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Overland Recycling System for Animal Waste Treatment

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OVERLAND RECYCLING SYSTEM FOR ANIMAL WASTE
TREATMENT

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows, (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries, and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American people.

William C. Galegar

William C. Galegar, Director
Robert S. Kerr Environmental
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ABSTRACT

The purpose of this research was to evaluate the technical and economic feasibility of an alternate disposal and utilization system of animal waste management in an operation involving overland spray for crop production. The system included two lagoons, one anaerobic and the other aerobic, in close proximity to the swine installation. These lagoons were used in series to dispose of the swine waste and to improve effluent quality for land application. Hence, there was a time lag with economic constraint to complete the cycle through a terminal aerobic lagoon.

A primary objective of this project was delineation of techniques for deriving nutrient benefits from animal wastes and making them directly available for selected crop production. In this respect, this investigation has contributed to developing a workable design that addresses itself to the evaluation of an overland spray system using animal wastes. For this purpose swine waste was transported into two adjacent lagoons and pumped through 7.6 centimeters (cm) PVC and improvised gas lines to irrigate three demonstration fields and 12 research plots equipped with runoff and soil water collection devices.

Vegetable crops were grown in the plots and animal forages were grown in the demonstration fields where growth responses were assessed. Preliminary soil analyses were conducted to determine the extent of uniformity of soil elemental contents. A soil profile determined successive depths for soil water sampling. Soil water from three trial periods was chemically analyzed for pH, chloride, specific conductance, nitrate, nitrite, and ammonia nitrogen. These parameters were meticulously evaluated with respect to their impact on the soil-plant-soil water system.

Inventories of feed consumption and swine numbers were maintained to assess the contribution to the lagoon system. Subsequent degradation processes were periodically examined with respect to the effect of the treatment units on nutrient preservation and effluent quality. In this study, emphasis was upon conservation and transformation processes of nutrients pursuant to the lagoon changes. Nitrogen-containing nutrients known to be valuable for adequate plant responses were appraised and the impact on the native ground water system was documented.

This report was submitted in fulfillment of Grant No. R-802336 by Alcorn State University under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period January 1, 1974 to January 30, 1978.

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SECTION I

INTRODUCTION

GENERAL

This was a three-year study to evaluate the technical and economical aspects of an alternate disposal and utilization system for swine waste management which incorporates overland spray irrigation for crop production and an anaerobic-aerobic lagoon system for effluent improvement.

The material presented in this report delineates changes in the constituents of aerobic effluent sprayed on crops as reflected by soil analyses before and after applications. Results of this study also serve to improve techniques for exploring the ecological effects of land recycling of animal waste and to present such ideas more meaningfully. Such knowledge is imperative if we are to develop regional or nationwide guidelines making livestock waste disposal methods compatible with public interests.

PERSPECTIVE AND BACKGROUND

More than 80 million hogs were produced and processed in 15 leading hog-producing states during 1969 (1). Thirteen and one-half million of these hogs were grown in the confinement of pigsties. The feedlot growing of hogs has been increasing rapidly in the Southeastern states. There is an increasing number of hogs grown in feedlots in Mississippi (2). In North Carolina, confinement structured units using lagoons constitute approximately 18 percent of all units (3). On a national basis, data indicate that the number of producers with enclosed units is increasing. In 1969, 26 percent of the producers from 15 of the leading hog-producing states utilized either a paved lot or confinement system of production (1).

In a study conducted in 1975 characterizing hog production systems on a national scale, the trend in production systems was toward dirt lots and total confinement (4). The pasture production system of hog production accounted for nearly one-third of all producers in 15 leading hog-producing states, most of whom were small producers (5). The amount of land required for pastures is quite large, and, in terms of land value in certain areas, pasture use for hog production represents a substantial part of the invested dollar. The use of pasture for hog production requires labor for fence and gate repair, handling of animals, and a small amount for waste management.

In certain sections of the United States and in other parts of the world, the terrain is hilly and wooded, which gives limited space for pastures or the production of crops for finishing hogs. Therefore, a system of enclosed confinement feeding and pasture-grazing is promising for economical production (6).

To utilize this system of production discretely, the producer must be cognizant of the limitations of pasture as a nutrient source and adjust his stocking rate accordingly. The number of animals per hectare can and should be regulated to insure efficient waste utilization for plant growth.

Establishing sufficient pasture vegetation for animal growth or maintenance is a natural means of waste utilization in the enclosed confinement-pasture-grazing system; however, it is necessary to remove the animals from the pasture during the dormant stage. This is required for adequate growth of winter grasses and legumes when used in a rotation scheme. An accompanying problem of waste disposal is apparent. The feeder pig type of production often requires a central farrowing house, and it is appropriate to pasture feed weaned sows and replacement gilts. Handling swine in this manner relieves congestion in the enclosed confinement areas and reduces the waste output to lagoons.

An enclosed confinement-pasture-grazing system of hog production offers potential because pasture grasses and legumes can utilize the nutrients in animal waste transported from lagoons. Overland application of animal waste offers promise as a method of disposal wherever land is readily available in the U.S. Several studies confirm use of this system as a means of removing concentrated nutrients from waste water (7, 8, 9, 10). Swine producers need to know the limiting number of hogs when defecated waste is applied to the land for crop production and how to adapt their crop production to the waste output of their swine unit.

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) were the focal points which directed attention to development of techniques for waste disposal that would be environmentally appropriate. The Environmental Protection Agency's standards centered around alternative systems that were economically sound, thus land application was a process which presented a challenge to the states (11).

The Congressional point of view is cited as conclusive and positive indication that land treatment is potentially an effective alternative and substantiates accord between the House and Senate on the effective role of crop land treatment with animal waste (12).

It was discerned that the need for regulations would arise and that certain theories and recommendations should be researched to serve as guides for states, municipalities, and Federal authority in the development of waste water and runoff water quality standards. Water quality standards for the land application alternative most generally apply to the constituents in ground water (13). In a study conducted to test the effectiveness of

overland recycling (14), soil water samples were collected weekly using porous ceramic samplers installed at depths of 46 to 61 cm and 122 to 132 cm. Effluent that was to be applied to land had mean values of 13.8 milligrams per liter (mg/l) for ammonium nitrogen ($\text{NH}_4\text{-N}$), 1.3 mg/l of nitrate nitrogen ($\text{NO}_3\text{-N}$), 319 mg/l of chloride (Cl), 8.20 for pH, and 1695 micromhos per centimeter conductivity ($\mu\text{ mhos/cm}$). Analysis of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in effluent showed that as $\text{NH}_4\text{-N}$ changed, there was a converse change in $\text{NO}_3\text{-N}$. Evidence revealed from mean monthly concentrations of nitrate in soil water (samples were taken at 122 cm depths) were 3.8 to 8.2 mg/l for 2.5 cm per week applications of effluent. At lower depths the concentration of nitrate was approximately 2 times as high (15).

Increased nitrogen removal from soil was observed as the application rate of nitrogen increased (16). Where a limited amount of nitrogen removal from soil occurred, there was very little ion removal by certain types of plants through harvesting (17). It was likewise concluded that in addition to soil infiltration, nitrogen removal from the soil is affected by the capacity of plant-soil systems to uptake and degrade nutrients and by the lack of physical transport of energy-containing nutrients to deeper strata for the denitrifiers. Crop removal of nitrogen in its various forms was highly recommended as a means of reducing these variables (14, 15).

SECTION II

CONCLUSIONS

1. In this study, peak periods of reductions from Cell 1 to Cell 2 were 94.44 percent for biochemical oxygen demand, 56.07 percent for specific conductance and 104.79 percent for ammonia nitrogen. The pH increased during the same period. These changes of chlorides, ammonia nitrogen, nitrate nitrogen, biochemical oxygen demand, pH and conductance varied with precipitation, number of animals, temperature and other factors after waste was transported from Cell 1 to Cell 2.
2. An additional decrease in $\text{NH}_3\text{-N}$ was observed after application to the soil-plant system to as little as 0 mg/l in some soil water samples. There were similar decreases in $\text{NH}_3\text{-N}$ for all soil water samples within treatments and at different depths, whereas chloride and nitrate nitrogen analyses varied from sample to sample within treatments.
3. After spraying, soil water had a Trial mean content of 8.64, 13.66, and 33.16 milligrams per liter of nitrate nitrogen for treatments A, B, and C, respectively. A substantial decrease in nitrate nitrogen occurred during Trial 3 compared to the preceding Trials. Reduction in nitrate nitrogen in the treatment material and of that which accumulated after treatment was important from a standpoint of improving water quality, and the method was economically sound since vegetable crops utilized it as a source of nitrogen.
4. The data for pH of soil water showed reductions from 7.42 to 6.90 and 7.54 to 5.95 after water, and effluent, respectively, were applied to the soil during Trial 1. Similarly, pH reductions were observed after Trial 2 and Trial 3.
5. The findings of this research indicated higher acidity in soil water after all trials than the pretreatment soil analysis because hydrogen ions were attached to clay particles in the soil, but were free in soil water. Increasing the volume of applications in successive trials was a form of induced anaerobic soil conditions wherein chemical reductions took place and H^+ ions were released without harmful effects to the vegetable crop.

6. Accumulated nitrate nitrogen was reduced in successive trials presumably by microbial denitrification of unassimilated nitrate nitrogen and was associated with release of hydrogen ions.
7. Chloride concentrations at all depths and after all trials, were evidence of treatment percolation and did not exceed acceptable levels for ground water.
8. Considerable aerobic lagoon and soil-plant post treatment reduction of specific conductance were noted.
9. The response of pasture forages on demonstration fields and selected grazing areas to aerobic effluent applications was very good. Vegetable crops also gave very good response.

SECTION III

RECOMMENDATIONS

1. Determine the extent of interaction between time after spraying and volume of application which may affect nitrate nitrogen concentration in soil-soil water-plant systems. More data are needed relating to nitrate nitrogen production after applying 2.5 cm or more of aerobic effluent per week for periods exceeding six weeks.
2. More data are needed on nitrate nitrogen production after overland spray so that recommendations can be made to producers who have large volumes of waste to dispose of on limited available land.
3. Investigate the effects of applying swine waste when concentrations of ammonia nitrogen in aerobic effluent exceed 75 milligrams per liter.
4. Investigate more thoroughly the chemical composition of the edible portion of livestock forages and vegetables when animal waste is used as a source of water and nutrients for plant growth.

SECTION IV

EXPERIMENTAL PROCEDURE

SWINE FACILITY AND LAGOON SYSTEM

The swine facilities consisted of one farrowing barn and a sow and boar shed. Concrete floors of both facilities were sloped to drain into concrete ditches which were adjacent to each facility. A 15.2 cm PVC sewer pipe transported the daily washing of swine waste (including spilled feed and animal hair) from these ditches to a concrete block collecting area 1.5 meters (m) in circumference and 2.1 m deep. The swine waste was further transported through 30.5 m of 15.2 cm PVC sewer pipe to an anaerobic lagoon.

The farrowing barn housed a maximum of 26 sows and their litters in individual pens. The boar and sow shed housed 3 boars in individual pens and 3 pens of 12 weaned sows per pen. Animals in these swine facilities were fed commercial feed rations that were nutritionally balanced for starting, growing, finishing and breeding purposes. Farrowing and weaned sows consumed 3.18 and 1.81 kilograms (kg) of feed per day, respectively. Each feeder pig consumed 1.51 kg of feed per day for approximately 60 days per year. There were 224,604 kg of feed consumed from January 30, 1974 through August 30, 1977 by all animals in the two facilities.

The lagoon system was designed to facilitate anaerobic and aerobic degradation of swine waste. The anaerobic lagoon had a capacity for 2678 cubic meters (m³) of swine waste before beginning to drain through a 15.2 cm PVC sewer pipe into the aerobic lagoon which had a capacity of 2153 cubic meters (m³) of swine waste. When filled to capacity, the aerobic lagoon would begin to drain through a 15.2 cm PVC sewer pipe into a valley 21.3 m beyond and into the river. Both lagoons were open to environmental weather conditions--effects of the sun and rain water. However, diversion ditches prevented most rain from going into the lagoons. Unlike lagoons receiving cattle waste, these swine waste lagoons had only a small quantity of feed debris from roughage intake to accumulate on the surface of the liquid. The amount of water in both lagoons was greater during the winter months than in summer due to greater rainfall and less evaporation.

OVERLAND SPRAY SYSTEM

Aerobic effluent was pumped to the irrigation sites with a 10.1 metric horsepower, 56.2 Kg/cm² pump via 442.3 m of 7.6 cm abandoned gas line. At

the irrigation site, a riser on riser valve continued the transport of effluent through a 10.2 cm aluminum aboveground irrigation line to three demonstration fields sprayed by standard overhead Rain Bird sprinklers. Underground 7.6 cm PVC pipes continued the transport of effluent to a concrete junction box which housed four regulator valves with underground irrigation wiring attached. A 7.6 cm PVC water line was also installed to transport tap water to this junction box. A 2.5 cm PVC water pipe continued from the junction box to 12 research plots - transporting tap water, tap water and effluent, and effluent only to four plots for each of these treatments. The plots were sprayed with Rain Bird pop-up sprinklers. Four strands (450 m each) of underground wiring connected a Rain Bird Rain Clox eight controller to four regulator valves in the junction box so that automation was controller--valve regulated. This system delivered the treatment volumes to plots on a timed basis (according to manufacturer's specifications) for selected days, morning and evening.

EXPERIMENTAL DESIGN

Three treatments were applied to the 12 research plots and will be referred to as treatments A, B, and C in subsequent discussions and tables.

Treatment A was tap water;
Treatment B was 50% tap water and
50% effluent; and
Treatment C was effluent.

There were four periods during the conduct of this study. These periods were delineated accordingly as:

Preapplication -- Period 1

No treatment was applied, so only baseline data were taken.

Trial 1 -- Period 2

Treatments A, B, and C were applied at a rate of 0.5 cm per application with three applications per week, making a total weekly application per plot of 1.5 cm. Treatments were applied on Monday, Wednesday, and Saturday for a period of four weeks (January 26, 1976 - February 28, 1976), giving a total of 7.6 cm per plot.

Trial 2 -- Period 3

Treatments A, B, and C were applied at a rate of 0.5 cm per application with six applications per week, making a total weekly application of 3.0 cm per plot. Treatments were applied Monday through Saturday from July 18 through September 6, 1976 for 36 days (eight days excluded), giving a total of 18.3 cm per plot.

Trial 3 -- Period 4

Treatment A, B, and C were applied at a rate of 0.5 cm per application with 12 applications per week, morning and evening, making a total weekly application of 6.1 cm per plot. Treatments were applied Monday through Saturday from June 13 through July 30, 1977 for a total of 36 days (applications were not made for six days during this period). A total of 36.6 cm for each treatment was applied per plot.

EXPERIMENTAL LAND PLOTS

The prepared irrigation site was on a grass and brush covered ridge that meandered through miles of woodland, and varied in width from 30 to 90 m with valley depths of 6 to 25 m on either side. Like most soil in this area, the soil in the research area is said to have been blown in and deposited during the dust bowl years of the 19th century. It is Memphis silt loam, easily eroded, and has the capacity to "take in" a large amount of water.

The site selected for demonstration and research purposes is 152 x 82 m. It was divided into four parts; three parts were used for demonstration fields and were designated as fields 1, 2, and 3 (Figure 1). The three demonstration fields were developed, sprayed with effluent, and chemical analyses were made for parameters of interest prior to establishing the research plots. The fields were to simulate conventional irrigation of cropland. Furthermore, waste handling mechanisms were studied as well as the means for evaluating the effects of defecated waste upon soil and soil water content and the response of selected forages and vegetables; namely, ladino clover, rye grass, bermuda grass, oats, tomatoes, collards, turnips, etc. A 6 x 6 m plot in each field was used for vegetable growth, sprayed along with the rest of the field, and provisions were made for collecting runoff effluent. Each field was 0.12 hectares.

The fourth part (32 x 41 m) of the irrigation site was subsequently divided into 12 research plots, 6 x 6 m, having 3.4 m of grass work area bordering each plot from all sides. The average slope was 3.8 cm. A typical plot was arranged so that runoff application from treatments A, B, and C flowed slowly from the plots into adjacent runoff ditches and thence into a cone-shaped collecting hole 38 cm in diameter at ground level and 45.7 cm deep. This runoff collecting hole was dug in a corner of each plot at the lowest elevation. A 35.5 cm strip of polyethylene (Visqueen) was used as lining for the runoff ditches -- tucked under the soil, slightly below the elevation of the plot and extending into the polyethylene-lined cone. A portion of polyethylene was cut 91.4 cm in diameter and then folded to fit the shape of the cone. Placement of lining material was done while the soil was moist to facilitate tucking and adherence to the soil's surface. Rain water was kept from draining onto the plots by a 10 to 12 cm dam or diversion ditch where required. Three soil water samplers having a porous ceramic cup on the below ground end were placed in each plot at depths of 15.2, 30.5, and 45.7 cm. The samples were evacuated with a manual suction pump and sealed.

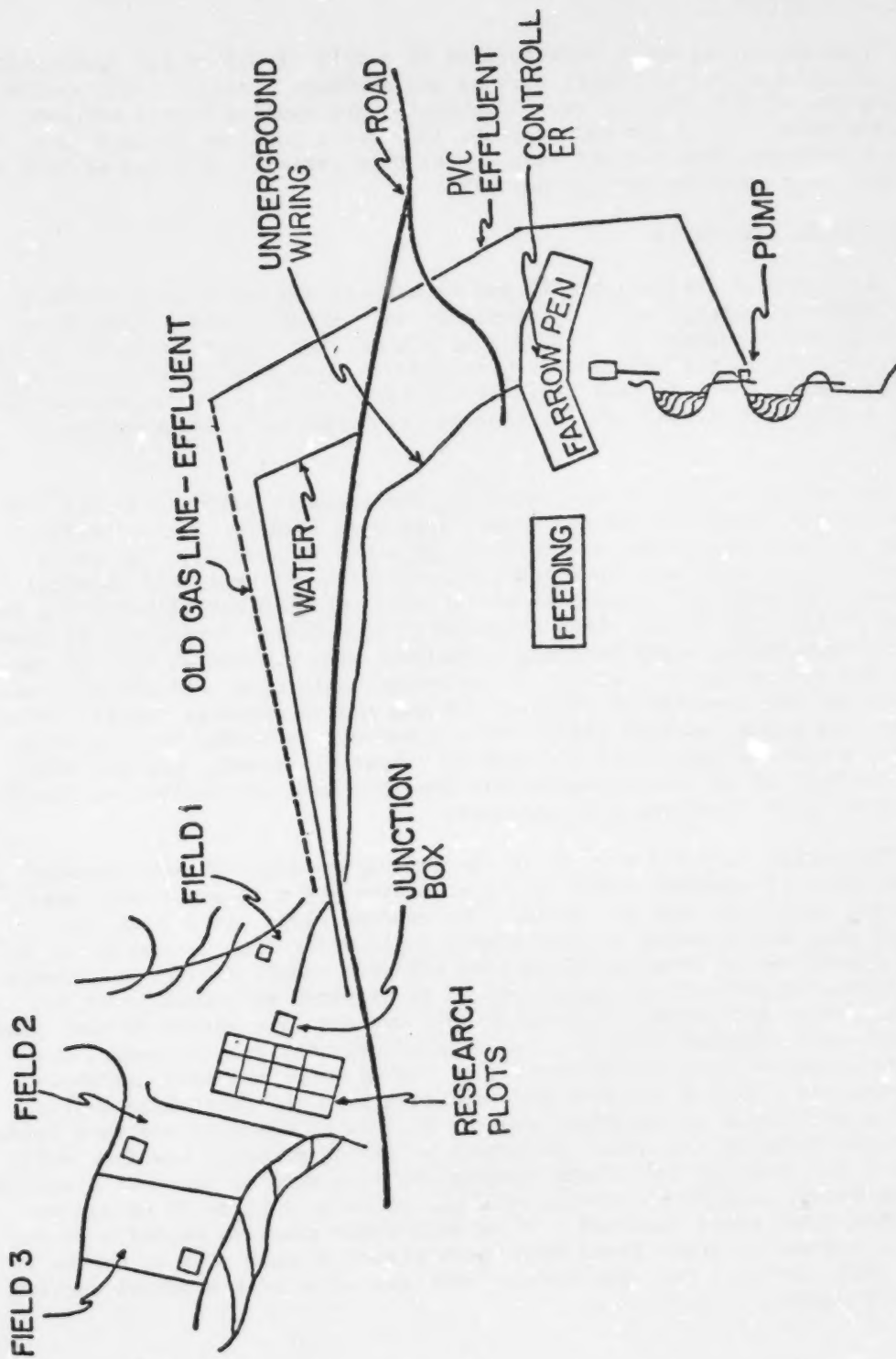


Figure 1. Feeding and overland treatment area.

A variety of vegetables consisting of blackeye peas, collards, turnips, tomatoes, etc., were planted, in season, on the prepared plots, so as to have similar varieties on each plot.

ANALYTICAL METHODS--CHEMICAL

Monthly analyses of the two lagoons were conducted for nitrite (NO_2), nitrate (NO_3) and ammonia (NH_3) nitrogen (N), pH, biochemical oxygen demand 5-day (BOD_5), chloride (Cl), conductance, and total coliform. Similar analyses of soil water samples were conducted with the exception of BOD_5 and total coliform.

Total coliform was determined using a membrane filter technique as described by the 13th Edition of Standard Methods for Examination of Water and Waste Water. The number of bacteria was reported as colonies per 100 milliliters (ml) of sample.

Pretreatment analyses of soil was done for pH by using a standard pH meter. Chloride concentration was determined by using the Mohr (silver nitrate) method. Post treatment chemical analyses of soil samples were conducted for nitrate- and ammonia-N, pH and chloride using a Lamotte soil analysis kit (Model STH-14).

Chemical analysis of soil water and effluent was done using the Hach DR/EL-2 Spectrophotometer Conductivity Meter. The analytical procedure involved in each analysis is detailed below.

Chloride: The Merwine nitrate titration method for water and wastewater analysis was used. Ten ml of the water or effluent samples were pipetted into a 50 ml Erlenmeyer flask. The contents of one diphenyl - carbasone indicator buffer powder pillow was added and mixed. While constantly swirling the flask, the sample was titrated with standard mercuric nitrate until the color changed from yellow to purple. From the number of ml of standard mercuric nitrate used, the mg/l of chloride concentration was determined.

Nitrate Nitrogen: Nitrogen as nitrate was determined using the cadmium reduction method for waste water analysis. Twenty-five ml of the water or effluent samples were placed in a clean spectrophotometric cell. To this was added the content of one nitrate V nitrate reagent powder pillow. The cell was stoppered and vigorously shaken for exactly one minute. It was allowed to stand for five minutes. Another clean spectrophotometric sample cell was filled with 25 ml of the water or effluent sample and placed in the spectrophotometric cell holder. The nitrogen nitrate (nitriver V method) meter scale was inserted in the meter and the wavelength dial adjusted to 500 millimeters (mm). The light control meter was then adjusted for a meter reading of zero mg/l. This sample cell was then removed and the first prepared sample in the cell was placed in the holder. The meter was read as mg/l of nitrate nitrogen. The shaking and standing time and the time difference between standing and final reading were kept constant in all the analyses. Results were expressed as mg/l nitrate (NO_3) by multiplying the mg/l nitrate nitrogen by 4.4. Interference from nitrate was removed by the addition of bromine.

Nitrite Nitrogen: Nitrite nitrogen was determined by the diazotization method using the registered nitriver III reagent. A 25 ml sample of the effluent was taken in a clean spectrophotometric cell and the contents of one nitriver III nitrite reagent powder pillow was added. After stoppering, the cell was shaken vigorously for exactly one minute and allowed to stand for 10 minutes. Another clean spectrophotometric cell was filled with 25 ml of the sample solution and placed in the cell holder. The nitrogen, nitrite (nitriver III) method meter was inserted in the meter scale and the wavelength dial adjusted to 500 mm. The light control switch was adjusted for a meter reading of zero mg/l. After this, the prepared sample cell was inserted in its place and the mg/l nitrite nitrogen reading was read on the meter scale. The results were expressed as mg/l of nitrite nitrogen by multiplying the mg/l of nitrite nitrogen by 3.3.

The shaking time, the standing time, and the difference between standing and final reading were kept constant in all the analyses.

Nitrogen Ammonia: This was determined using Nessler's method. A 25 ml sample of the effluent was placed in a clean spectrophotometric sample cell. Twenty-five ml of demineralized water (prepared by using the carbon ion exchange resin) was placed in another cell. To each of these samples was added one ml of Nessler's reagent using a one ml calibrated dropper. The samples were swirled to mix. After 10 minutes, the sample cell containing the prepared demineralized water solution was placed in the spectrophotometer holder. The ammonium nitrogen meter scale was inserted and the wavelength dial adjusted to 425 mm. The light control switch was then adjusted for a meter reading of zero mg/l. Then, this cell was removed and the other cell containing the prepared effluent solution was introduced. The scale was read as mg/l of ammonia nitrogen. The result was expressed as mg/l of $\text{NH}_3\text{-N}$ by multiplying the final scale reading by 1.22.

Specific Conductance: The sample was neutralized by mixing the contents of one powder pillow (gallic acid 0.2g) with approximately 50 ml of sample. If the gallic acid remained undissolved, four drops of phenolphthalein solution were added to 50 ml of sample and then gallic acid was added until the pink color completely disappeared.

Biochemical Oxygen Demand: Biochemical Oxygen Demand was determined by the Hach BOD₅ apparatus, Model 2173, which combined the features of the standard type manometric apparatus by Warburg and Sierp. Samples were allowed to run for five days at 20°C, then values were reported as mg/l.

STATISTICAL ANALYSIS

Treatments A, B, and C were assigned at random to the 12 research plots before installation of the spray system. It was hypothesized that no significant differences in plots would be found among pretreatment samples since no application of treatments was made on the plots. Preliminary analysis of variance indicated there were no differences in the plots to begin with; therefore, post treatment difference, if any, would indicate effects due to treatments.

The analysis of variance to test post treatment data Table 1 was a split plot design with treatments in a completely random design in the whole plots.

TABLE 1. ANALYSIS OF VARIANCE: TEST FOR CHANGE IN VARIABLES AFTER OVERLAND SPRAY FOR TRIALS 1, 2, AND 3

Source of Variation	df
Treatments	2
E _a	9
Depths	2
T X D	4
E _b	18

All analyses were performed on data for main treatment effects and effects due to depth according to the methods of Steel and Torrie (18). There were four replications of each treatment, designated 1, 2, 3, and 4. Mean values are averages obtained from four plots receiving either treatment A, B, or C.

The analysis of variance for comparing NO₃-N data Table 2 immediately after spraying and 135 days after spraying of plots was a split-split plot design.

TABLE 2. ANALYSIS OF VARIANCE: COMPARISON OF NITRATE NITROGEN IN SOIL WATER IMMEDIATELY AFTER SPRAYING AND AFTER 135 DAYS

Source	df	F
Treatment	2	N.S
Error a	9	
Depth	2	<1
Treatment X depth	4	
Error b	18	
Time	1	12.90**
Treatment X time	2	8.90**
Depth X time	2	5.93**
Treatment X depth X time	4	3.00**
Error c	20	

** Significant at .01 level.

The analysis of variance for a split-split plot gave a significant second order interaction involving treatment, depth and time. The data were analyzed, therefore, within depths to determine the effects of treatment and time. Because of variance between plots, within treatment variance between treatment means within time was tested.

An analysis was made of the combined data (Table 3) from the three trials for ammonia nitrogen and nitrate nitrogen using a split plot design to test for significant differences due to source of variance. The combined analysis for ammonia nitrogen gave error terms that were similar and $E_a < E_b < E_c$, so all errors were pooled to have one error.

TABLE 3. ANALYSIS OF VARIANCE: COMPARISON OF THE MEAN CHANGES FOR AMMONIA NITROGEN FOR ALL TREATMENTS--TRIALS 1, 2, AND 3

Source of variation	df	SS	MS	F
Treatment	2	30395.8456	15197.9228	***
Depth	2	1.6898	0.8449	ns
Volume	2	1670.1681	835.0841	***
Treatment x depth	4	3.1902	0.7976	ns
Treatment x volume	4	1103.3887	275.8472	***
Depth x volume	4	6.1530	1.5382	ns
Treatment x depth x volume	8	9.5989	1.1999	ns
Error	81	96.3570	1.1896	

***Significant at the .001 level.

The combined analysis for nitrate nitrogen (Table 4) gave error terms as were expected using the following analysis of variance.

TABLE 4. ANALYSIS OF VARIANCE: COMPARISON OF THE MEAN CHANGES FOR NITRATE NITROGEN FOR ALL TREATMENTS--TRIALS 1, 2, AND 3

Source of variation	df	SS	MS	F
Treatment	2	5186.0830	2593.0415	6.85*
Ea	9	3404.5330	378.2814	
Depth	2	234.7070	117.3535	<1.12ns
Treatment x depth	4	385.0163	96.2541	<1ns
Eb	18	1892.4939	105.1385	
Volume	2	844.5727	422.2864	6.24**
Treatment x volume	4	916.7203	229.1801	3.39*
Ec	18	1217.4329	67.6352	
Depth x volume	4	56.8795	14.2199	< 1ns
Treatment x depth x volume	8	321.6883	40.2110	< 1ns
Ed	33	2195.8820	66.5419	

*Significant at .05 level.

**Significant at .01 level.

The means of both variables were separated wherever the source of variance was significant using DNMRT.

SECTION V

PRELIMINARY DATA--PERIOD 1

The application of aerobic effluent to three demonstration fields was initiated in the fall of 1974. A rye-oats-clover mixture was planted in the three fields in the early fall of 1974 followed by a planting of bermuda in early spring of the next year. Application of defecated swine waste was begun shortly after seeding. The applied waste was the only source of plant nutrients. It was applied to the 0.12 hectare fields on a timed basis in the proportion 1:2:3 for fields numbered 1, 2, and 3, respectively. Defecated lagoon waste was applied at a rate of 1.9 cm per hour so that minimal tensiometer readings for good growth were maintained. These fields were used to investigate management practices for applying animal waste to cropland using conventional Rain Bird sprinklers having 1.5 m risers on 10.1 cm aluminum pipe. Also, techniques for collecting waste runoff and soil water samples, plot size, and crop response were studied.

Runoff was difficult to handle using 94.6 liter containers embedded 1.8 m from 6 x 6 m plots within the fields, with roof gutters, down spouts, etc., to transport the runoff. The slope of one percent caused some flooding of the 6 x 6 m plots by rain water from the surrounding area. Runoff of effluent was high because of excess slope. Growth response of rye grass, clover, bermuda grass, and oats was very encouraging on all fields. Field 3 had the highest rate of application (1.9 cm per hour). Spraying of aerobic effluent on field 3, in late spring, caused about one-fourth of the plant foliage to drop to the ground, adhere to the soil, and decay.

On all three demonstration fields, as the duration of spraying of the aerobic lagoon effluent increased, the changes in all parameters measured, with the exception of ammonia nitrogen, also increased (Table 5). Each value in Table 5 represents the difference between the soil and the aerobic lagoon effluent for that particular parameter.

TABLE 5. CHANGE IN SOIL CONTENTS AFTER SWINE WASTE WAS SPRAYED FROM AEROBIC LAGOON^a TO FIELDS

Field	Soil Depth (cm)	Volume Sprayed (cm)	Time Sprayed (hr.)	Parameters					Specific Conductance (μmhos/cm)
				Cl	NO ₃ -N	NO ₂ -N	NH ₃ -N	pH	
				mg/l					
1	91	1.96	1.08	10	2.20	-.033	-.49	0.55	-90
2	91	3.91	2.16	35	6.60	-.029	-.06	-0.10	15
3	91	5.88	3.25	25	11.20	.182	-.37	1.50	111

^a Aerobic effluent -25 mg/l chloride, 13.2 mg/l nitrate, 0.0 mg/l nitrite, 25.93 mg/l ammonia, 2 mg/l oxygen, pH 7.6 and 600 μmhos/cm conductance.

Field application of effluent was studied from December 1974 through March 1975. Then the strategy for researching overland application of waste was changed to use of plots and more sophisticated methods of controlling the application process. Pretreatment analyses of the soil in these plots at depths of 15.2, 30.5 and 45.7 cm were conducted to ascertain the degree of uniformity among the plots.

Results in Table 6 show uniform pH among the 12 plots at all depths. This was an expected observation since nothing had been applied to the plots. The chloride content of the soil over all plots was considerably uniform before application with the exception of the 10 mg/l values (Table 7). Another study indicated that the chloride concentration of soils tend to vary among samples even when they are taken in close proximity of each other (19). There were no significant differences ($P < 0.01$) in chloride concentration among depths of 15.2, 30.5, and 45.7 cm, which indicated that percolation of water through the soil in all plots was uniform. Chloride analyses are useful to monitor the impact of the treatment percolates because negatively charged chloride ions do not adhere to the soil (20, 21). Preliminary analysis of the soil for chloride content yielded results which indicated a potential to reduce the chloride concentration of aerobic effluent when it is sprayed overland. It is possible that this could be accomplished by the uptake of the chloride ions in aerobic effluent by the soil and by plant tissue. Salt concentration in soil, measured by electrical conductivity (22), increased with increased rates of application of swine waste. Also, soil chloride concentration increased from 1.87 milliequivalents per liter (meq/l) (66.30 mg/l) to 6.80 meq/l (241.08 mg/l) at depths from 30.5 cm. When swine waste was applied to cropland (23), corn leaves showed significant increases in phosphorus and sodium at the 0.05 and 0.01 confidence level, respectively, as the volume of lagoon liquid was increased. In this current study, nitrogen analyses were impractical for preliminary soil samples because the excess time between taking the samples and analyzing them had contributed to a loss of most of the nitrogen.

TABLE 6. pH OF SOIL AT VARIOUS DEPTHS BEFORE IRRIGATION

Proposed Replication	Depth (cm)	Proposed Treatments			
		A	B	C	
1	15.2	5.40	5.30	5.45	
	30.5	5.45	5.65	5.45	
	45.7	5.80	5.45	5.70	
2	15.2	5.40	5.80	5.65	
	30.5	5.65	5.80	5.65	
	45.7	5.90	5.90	6.05	
3	15.2	5.80	5.70	5.45	
	30.5	5.45	5.80	5.45	
	45.7	5.90	5.45	5.70	
4	15.2	5.40	5.40	5.30	
	30.5	5.20	5.45	5.30	
	45.7	5.30	5.70	5.40	
Mean Values	15.2	5.50	5.55	5.46	5.50 ^a
	30.5	5.41	5.67	5.41	5.50 ^a
	45.7	5.72	5.62	5.71	5.68 ^a
		5.54 ^a	5.61 ^a	5.53 ^a	

^aMean values followed by a common letter are similar as determined by DNMRT (P < .01).

TABLE 7. CHLORIDE CONTENT OF SOIL AT VARIOUS DEPTHS BEFORE IRRIGATION

Proposed Replication	Depth (cm)	Proposed Treatments		
		A	B	C
		mg/l		
1	15.2	6.50	7.50	10.00
	30.5	7.50	7.50	8.50
	45.7	7.00	10.00	7.25
2	15.2	7.50	7.50	6.50
	30.5	7.50	7.50	6.50
	45.7	7.00	7.00	6.50
3	15.2	6.50	7.50	7.50
	30.5	6.00	7.50	7.50
	45.7	6.00	7.50	7.50
4	15.2	6.00	6.50	7.50
	30.5	6.50	7.50	7.50
	45.7	6.50	7.50	7.50
Mean Values	15.2	6.63	7.50	7.88 7.34 ^a
	30.5	6.88	7.50	7.50 7.30 ^a
	45.7	6.63	8.00	7.18 7.27 ^a
		6.71 ^a	7.67 ^a	7.52 ^a

^aMean values followed by a common letter are similar as determined by DNMRT (P <.01).

SECTION VI

TRIAL 1--PERIOD 2

Anaerobic and aerobic effluents were analyzed monthly for the parameters used to evaluate the environmental pollution abatement problems of this study. Results of chemical and bacteriological analyses of the liquids used for treatments A and C (Trial 1) are given in Table 8.

TABLE 8. MEAN VALUES OF AEROBIC EFFLUENT AND TAP WATER USED AS IRRIGATION SPRAY ON PLOTS OF FIELDS--TRIAL 1

Parameters	A	C
Chloride, (mg/l)	15.00	40.00
NO ₃ -N, (mg/l)	17.60	12.00
NO ₂ -N, (mg/l)	0.00	0.59
NH ₃ -N, (mg/l)	0.00	38.74
BOD, (mg/l)	5.00	40.00
Specific Conductance, (μ mhos/cm)	300.00	728.00
pH	7.42	7.54
Coliform, (colonies/100 ml)	0.00	200-1600

The analysis for treatment B was not done because of an oversight. Values represent analysis of the treatments at the time of application to the plots. BOD₅ values of 200-1600 mg/l for aerobic effluent indicate the demand for oxygen that waste water from lagoon cells will exert on the land disposal site. The type of collection device used to take soil water samples precluded the possibility of obtaining coliform values because of its filtering actions. Other bacteria are also prevented from entering the semiporous sample collecting device; consequently, BOD₅ analyses of soil water were not practical. However, bacteria will be available for action in the soil, thus lowering BOD₅.

Soil water data for pH, chlorides, nitrate and ammonia-N after treatment were compared with treatment concentration of these constituents and reported as change in concentration in soil water after application.

Analyses of soil water from plots after application of treatment A, B, and C indicated that pH decreased with penetration downward through the soil, accounting for greater change in pH values as the depths increased.

Analyses were less for all values (exception of one) after treatments were applied to the plots, even for tap water. There was a significant difference between the change of pH ($P < .01$) at all application rates, Table 9.

TABLE 9. CHANGE IN pH AFTER TREATMENTS WERE SPRAYED OVERLAND AS MEASURED IN SOIL WATER AT DIFFERENT DEPTHS

Replication	Depth (cm)	Treatment			
		A	B	C	
_____ change in pH units _____					
1	15.2	-0.64	-1.29	-1.01	
	30.5	-0.35	-0.99	-1.90	
	45.7	-0.77	-1.54	-1.64	
2	15.2	-0.90	-0.10	-1.19	
	30.5	-0.60	-1.44	-1.94	
	45.7	-0.85	-0.99	-2.04	
3	15.2	-0.07	-0.24	-1.74	
	30.5	-0.30	-0.89	-1.76	
	45.7	-0.09	-1.64	-1.39	
4	15.2	-0.35	-1.09	-1.64	
	30.5	-0.50	-1.12	-1.54	
	45.7	-1.00	-0.85	-1.44	
Mean Values	15.2	-0.49	-0.68	-0.85	0.67 ^a
	30.5	-0.44	-1.11	-1.10	0.88 ^{a,b}
	45.7	-0.63	-1.25	-1.17	1.02 ^b
		-0.52 ^a	-1.01 ^b	-1.59 ^c	

a,b,c Mean values not followed by a common letter differ as determined by DNMRT, ($P < .01$).

Differences between post treatment soil water values for chloride concentration and treatment concentrations of chloride are shown in Table 10. The first column of Table 10 is the difference in chloride concentration of soil water post treatment values and chloride concentration in tap water. There was an increase in negative value from 15.2 to 30.5 cm which means

there was less chloride at the 30.5 cm depth. More chloride is in the 45.7 cm depth than the 30.5 cm depth. Chloride ions and clay particles have the same negative charge, thus the chloride ions should move downward in the soil along with water movement. Tap water sprayed overland gave least change in chloride content of soil water after treatment. There were significantly greater changes ($P < .05$) in chloride content of soil water after treatment with 0.25 and 0.51 cm of aerobic effluent per application. Significant ($P < .05$) differences in change of chloride content due to depth were noted.

TABLE 10. CHANGE IN CHLORIDE AS MEASURED IN SOIL WATER AT VARIOUS DEPTHS¹

Replication	Depth (cm)	Treatment		
		A	B	C
		mg/l		
1	15.2	10	-10	5
	30.5	- 5	-10	-25
	45.7	0	-25	40
2	15.2	5	- 5	-25
	30.5	0	-15	-15
	45.7	0	-15	- 5
3	15.2	20	-15	- 5
	30.5	5	-10	-20
	45.7	5	-10	-15
4	15.2	0	-15	10
	30.5	0	-15	-25
	45.7	0	-10	-25
Mean Values	15.2	9	-11	- 4 - 2 ^a
	30.5	0	-12	-21 -11 ^b
	45.7	1	-15	- 1 - 5 ^a
		3.3 ^a	-13 ^b	- 9 ^b

^{a, b} Mean values not followed by a common letter differ as determined by DNMR, ($P < .05$).

¹ Values represent difference between treatments and soil water analysis.

There were no significant differences ($P < .05$) in change of nitrate concentration with depth when aerobic effluent was sprayed overland (Table 11). Nitrate-N should behave similarly to chloride ions, i.e., show some apparent increase as the soil depth increases because it also has the same negative

change as the soil. The slight difference in the amount of nitrate-N in the top 15.2 cm of soil as compared with lower depths for treatments A and B is not only due to the addition of effluent but also accounted for by the nitrification of the organic matter which is constantly taking place in the top soil. Nitrate-N ion concentration increased significantly ($P < .05$) when aerobic effluent containing 12.08 mg/l $\text{NO}_3\text{-N}$ was sprayed overland (Table 11).

TABLE 11. CHANGE IN $\text{NO}_3\text{-N}$ CONCENTRATION AFTER TREATMENTS WERE SPRAYED OVERLAND

Replication	Depth (cm)	Treatment			
		A	B	C	
		mg/l			
1	15.2	-4.40	22.00	13.40	
	30.5	----	0.50	11.20	
	45.7	1.76	0.90	20.00	
2	15.2	-4.40	9.00	18.24	
	30.5	-2.20	15.60	46.40	
	45.7	1.76	9.44	29.20	
3	15.2	4.40	9.00	36.28	
	30.5	-1.76	----	11.20	
	45.7	-4.40	15.60	24.40	
4	15.2	4.40	12.52	9.00	
	30.5	-6.40	11.20	20.00	
	45.7	-4.40	16.48	20.00	
Mean Values	15.2	0.00	13.13	19.23	10.78 ^a
	30.5	-3.45	9.10	22.20	9.28 ^a
	45.7	-2.20	10.61	23.40	12.07 ^a
		-1.88 ^a	10.94 ^b	21.61 ^c	

a, b, c Mean values not followed by a common letter differ as determined by DNMRT, ($P < .05$).

Pretreatment and post treatment data were compared to determine change in concentration of chloride in soil water after overland application (Table 12). Since a lapse of about 60 days occurred between pre- and post treatment sampling and analysis, it is quite likely that frequent rainfall affected results and the change in mean aerobic effluent concentration after overland application, as given in Table 10 may be more meaningful.

TABLE 12. CHANGE IN CHLORIDE CONTENT OF SOIL WATER AFTER OVERLAND APPLICATION OF TREATMENTS

Replication	Depth (cm)	Treatment		
		A	B	C
		mg/l		
1	15.2	0.00	-10.00	8.00
	30.5	0.00	-10.00	- 2.00
	45.7	0.00	0.00	6.00
2	15.2	5.00	5.00	- 5.00
	30.5	0.00	0.00	10.00
	45.7	-10.00	0.00	- 5.00
3	15.2	- 5.00	-10.00	0.00
	30.5	5.00	- 5.00	- 5.00
	45.7	5.00	-10.00	-10.00
4	15.2	- 5.00	----	----
	30.5	0.00	-10.00	-15.00
	45.7	0.00	5.00	-10.00
Mean Values	15.2	- 1.25	- 5.00	- 6.50 -4.17 ^a
	30.5	1.25	- 6.25	- 3.00 -2.67 ^a
	45.7	- 1.25	- 1.25	- 4.75 -2.42 ^a
Depth Mean		- 0.42 ^a	- 4.17 ^b	- 4.75 ^b

^{a, b} Mean values not followed by a common letter differ as determined by DNMR, (P < 0.05).

A study of Table 13 indicates the effectiveness of the nitrification process in converting ammonium salts to other components when aerobic effluent is sprayed overland. The negative values in Table 13 mean that the concentration $\text{NH}_3\text{-N}$ are that much less in soil water after various treatments than in aerobic effluent, e.g., wherever the value -38.74 occurs in Table 13 all $\text{NH}_3\text{-N}$ which was in treatments B and C was reduced to zero after land application.

TABLE 13. CHANGE IN AMMONIA NITROGEN CONCENTRATION AFTER TREATMENTS WERE SPRAYED OVERLAND

Replication	Depth (cm)	Treatment			
		A	B	C	
		mg/l			
1	15.2	0.07	-15.74	-28.37	
	30.5	0.00	-14.57	-38.74	
	45.7	0.09	-15.87	-38.42	
2	15.2	0.00	-15.87	-38.41	
	30.5	0.00	-15.87	-38.22	
	45.7	0.00	-15.87	-38.34	
3	15.2	0.24	-14.71	-38.24	
	30.5	0.00	-15.87	-38.51	
	45.7	0.00	-15.13	-38.58	
4	15.2	0.00	-15.87	-38.62	
	30.5	0.00	-15.87	-38.62	
	45.7	0.00	-15.87	-38.08	
Mean Values	15.2	0.08	-15.55	-38.41	-25.64 ^a
	30.5	0.00	-15.55	-38.52	-25.66 ^a
	45.7	0.02	-15.69	-38.36	-25.64 ^a
		0.03 ^a	-15.60 ^b	-38.43 ^c	

^{a,b,c} Mean values not followed by a common letter differ as determined by DNMR, (P < 0.05).

SECTION VII

TRIAL 2--PERIOD 3

The second application of overland spray was conducted daily--six times per week for 36 days on the same plots as applications for period one. There was a lapse of four and a half months between the end of Trial 1 and the beginning of Trial 2. The chemical and bacteriological analyses for constituents of the liquids used for treatments A, B, and C during Trial 2 are given in Table 14.

TABLE 14. ANALYSES OF TREATMENTS A, B, AND C USED AS IRRIGATION SPRAY ON PLOTS AND FIELDS--TRIAL 2

Parameter	A	B	C
Chloride, (mg/l)	15.00	30.00	61.25
NO ₃ -N, (mg/l)	4.40	0.30	0.70
NO ₂ -N, (mg/l)	0.00	0.0165	0.4000
NH ₃ -N, (mg/l)	0.00	22.50	52.09
BOD, (mg/l)	0.00	----	52.09
Specific Conductance, (Micromhos/cm)	300.00	560.00	1139.00
pH	7.15	8.00	8.08
Coliform, (colonies/100 ml.)	0.00	2500.00	4,040.00

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Change in pH was twice as high for the second period of application compared with the first application (Table 15). There were no significant differences in the change of pH ($P < .05$) related to depth of infiltration. This fairly uniform pH indicates uniform infiltration of soil water after overland spray. There was a significant greater ($P < .05$) reduction in pH for two levels of effluent spray when compared with the application of water only.

TABLE 15. CHANGE^a IN pH AFTER VARIOUS TREATMENTS WERE SPRAYED OVERLAND

Replication	Depth (cm)	Treatment			
		A	B	C	
_____change in pH units_____					
1	15.2	1.15	2.00	2.18	
	30.5	.58	2.30	2.08	
	45.7	1.05	2.31	1.83	
2	15.2	1.15	1.90	2.29	
	30.5	.83	1.99	2.51	
	45.7	1.21	----	2.48	
3	15.2	1.15	1.85	2.10	
	30.5	1.12	2.06	1.68	
	45.7	.96	1.73	2.06	
4	15.2	1.45	2.33	2.08	
	30.5	.83	1.59	2.13	
	45.7	1.20	2.00	1.96	
Mean Values	15.2	1.22	2.02	2.16	1.80 ^a
	30.5	.84	1.73	2.10	1.55 ^a
	45.7	1.10	2.01	2.08	1.73 ^a
		1.05 ^a	1.92 ^b	2.11 ^b	

^aAll values negative (this much less in soil water than treatments).

^{a,b}Mean values not followed by a common letter differ as determined by DNMRT, (P < .01).

Results pertaining to change in chloride contents of the various treatments are shown in Table 16. There was only slight variation in the samples taken from the same depth from plot to plot. Somewhat more variation in samples was observed for nitrate nitrogen. Results, in this respect, show some similarity to another observation which indicated that water soluble nitrate and chloride are not affected by the exchange complex of the soil matrix, causing much greater variation from sample to sample (12). Results over all treatments for the 45.7 cm depth than for lesser depths when treatment was applied to the land.

There was a mean difference of 13.25 mg/l less chloride in soil water after applying treatment C to the soil (Table 16) than in treatment C which contained 61.25 mg/l of chloride ions (Table 14).

TABLE 16. CHANGE IN CHLORIDE CONTENT AFTER TREATMENTS WERE SPRAYED
OVERLAND, TRIAL 2

Replication	Depth (cm)	Treatments			
		A	B	C	
		mg/l			
1	15.2	15.00	- 5.00	-18.50	
	30.5	2.00	-10.00	-36.00	
	45.7	0.00	- 5.00	14.00	
2	15.2	15.00	7.50	-31.00	
	30.5	15.00	12.50	-13.50	
	45.7	5.00	-----	-33.00	
3	15.2	15.00	7.50	19.00	
	30.5	2.50	- 7.50	-13.50	
	45.7	5.00	2.50	-31.00	
4	15.2	- 5.00	- 3.75	1.50	
	30.5	0.00	0.00	34.00	
	45.7	0.00	-10.00	-21.00	
Mean Values	15.2	10.00	1.56	- 7.25	1.43 ^a
	30.5	4.87	- 1.25	-14.75	-3.71 ^a
	45.7	2.50	- 4.16	-17.75	-6.47 ^b
		5.79 ^a	1.28 ^a	-13.25 ^b	

^{a, b} Mean values not followed by a common letter differ as determined by
DNMRT, (P < .01).

(-----) A sample was not available for this depth.

In Table 17, it can be seen that the mean of NO₃-N was greater 135 days after application of treatment at two levels of applicaiton. These samples were analyzed at the end of the rainy season of November through February and the results are very similar to predictable nitrate distribution in the soil profile (24) which showed greatest concentration of NO₃-N (in µg/g) at a depth of 35.6 cm after infiltration by 5.1 cm of rainfall.

When the concentrations of NO₃-N in soil water after Trial 1 were compared with concentrations of NO₃-N 135 days later (Table 17), analysis of variance gave a significant second order interaction involving treatment, depth and time (P < .01). Because of this, the data were analyzed within depths to determine the effects of treatment and time. There were no significant sources of variance in either depth 1 or depth 2, but at depth 3 the

TABLE 17. NITRATE CONTENT OF SOIL WATER AT VARIOUS DEPTHS IMMEDIATELY AFTER SPRAYING AND 135 DAYS AFTER SPRAYING

Replication	Depth (cm)	Treatment					
		A		B		C	
		mg/l					
1	15.2	*	**	*	**	*	**
	30.5	13.20	10.00	10.80	31.00	14.08	14.00
	45.7	2.20	5.00	---	119.00	---	14.00
2	15.2	4.40	9.00	36.08	61.00	---	18.00
	30.5	2.20	4.40	19.30	9.00	13.20	35.00
	45.7	2.64	6.00	3.08	18.00	37.50	22.00
3	15.2	2.20	18.00	---	8.00	25.52	---
	30.5	3.52	1.00	71.28	53.00	41.00	2.00
	45.7	4.40	3.10	2.64	37.00	13.20	1.00
4	15.2	---	18.00	3.50	18.00	6.60	2.00
	30.5	1.76	13.00	8.80	40.00	2.08	3.00
	45.7	4.84	97.00	---	60.00	11.00	10.00
Mean Values	15.2	3.52	18.00	11.00	30.00	6.00	4.00
	30.5	5.17	7.10	27.54	33.25	17.59	13.50
	45.7	3.52	27.77	2.86	58.50	20.59	11.75
		3.37	15.75	16.86	29.25	12.70	8.00
		4.02	16.87	15.75	40.33	16.79	11.08

*Immediately after irrigation - 1st Trial.

**135 days after irrigation.

----No sample.

interaction between treatment and time was significant ($P < .05$) (Table 18). Presumably, a substantial part of the nitrogen removed from the soil by vegetable growth was returned since the vine portion containing assimilated nitrogen was returned to the soil during the 135 days.

TABLE 18. TREATMENT (NITRATE) MEANS AFTER SPRAYING AND 135 DAYS LATER - DEPTH, 45.7 CENTIMETERS

Time	Treatment		
	A	B	C
	mg/l		
1	(3)* 3.37 ^b	(3) 16.86 ^{ab}	(3) 12.70 ^{ab}
2	(4) 15.75 ^{ab}	(4) 29.25 ^a	(3) 8.00 ^{ab}

^{ab} Means not followed by the same letter differ ($P < .05$) as determined by DNMRT.

*Numbers enclosed with parenthesis are number of observations in the mean.

After the second period of spraying, the reduction of $\text{NH}_3\text{-N}$ in aerobic effluent was almost complete, inasmuch as the maximum values obtained in soil water analysis were 0, 0.60, and 4.50 mg/l after spraying with 0, 50, and 100 percent aerobic effluent, respectively. All values were rather uniform (standard deviation ± 0.0842) among these samples. The effectiveness of the nitrification process can be seen by referring to the values shown in Table 14. Aerobic effluent may be seen to contain 52.09 mg/l and the aerobic effluent-water mixture 22.50 mg/l of $\text{NH}_3\text{-N}$. Results in Table 19, showing reductions of $\text{NH}_3\text{-N}$, are almost equivalent to the analysis of treatment B and C before application. For the second period application of overland spray, Table 20 shows that the mean increase of nitrate N at the 15.2 cm depth was greater than depths of 30.5 or 45.7 cm. Rainfall during this period of application was negligible, and may have been responsible for the limited amount of soil infiltration of $\text{NO}_3\text{-N}$.

Applying twice as much of all treatments during Trail 2 than during Trial 1 gave findings of 0.77, 4.72, and 0.06 mg/l mean increase in $\text{NO}_3\text{-N}$ for treatments A, B, and C, respectively. There was no significant ($P^3 < 0.05$) difference in change of $\text{NO}_3\text{-N}$ for 0.25 and 0.51 cm of aerobic effluent application but changes were significantly greater ($P < 0.05$) at these two levels of effluent than when water only was applied.

The nitrification process yielded 60 to 40 percent of $\text{NH}_3\text{-N}$ to $\text{NO}_3\text{-N}$ conversion after application of treatments B and C as measured in soil water.

TABLE 19. CHANGE IN NH₃-N CONTENT AFTER VARIOUS TREATMENTS WERE SPRAYED OVERLAND

OVERLAND					
Replication	Depth (cm)	Treatment			
		A	B	C	
		mg/l			
1	15.2	-0-	-22.40	-51.99	
	30.5	-0-	-22.22	-52.09	
	45.7	-0-	-21.82	-52.09	
2	15.2	-0-	-22.50	-52.09	
	30.5	-0-	-22.50	-52.09	
	45.7	-0-	-----	-52.09	
3	15.2	-0-	-22.48	-52.09	
	30.5	-0-	-21.40	-47.58	
	45.7	-0-	-22.49	-52.09	
4	15.2	-0-	-22.31	-52.06	
	30.5	-0-	-22.50	-52.04	
	45.7	-0-	-22.18	-51.80	
Mean Values	15.2	-0-	-22.42	-52.06	-24.82 ^a
	30.5	-0-	-22.15	-50.95	-24.36 ^a
	45.7	-0-	-22.18	-52.02	-24.73 ^a
		-0- ^a	-22.25 ^b	-51.61 ^c	

a,b,c Mean values not followed by a common letter differ a determined by DNMRT (P < .05)

----No sample

TABLE 20. CHANGE IN NO₃-N CONTENT AFTER TREATMENTS WERE SPRAYED OVERLAND

Replication	Depth (in.)	Treatment			
		A	B	C	
mg/l					
1	15.2	8.80	13.56	26.10	
	30.5	- 2.20	23.90	24.56	
	45.7	1.20	35.34	1.49	
2	15.2	2.20	18.59	27.89	
	30.5	12.32	6.08	40.04	
	45.7	14.30	-----	47.25	
3	15.2	- 0.22	45.10	32.99	
	30.5	- 0.22	3.22	10.29	
	45.7	- 1.21	6.95	19.09	
4	15.2	- 2.64	5.20	13.53	
	30.5	0.44	3.21	9.19	
	45.7	- 0.88	9.60	7.65	
Average	15.2	2.03	20.61	25.12	15.92 ^a
	30.5	2.58	9.10	21.02	10.69 ^a
	45.7	3.35	17.29	18.87	13.17 ^a
		2.65 ^a	15.66 ^b	21.67 ^b	

a,b Mean values not followed by a common letter differ as determined by DNMRT, (P < .05).

-----No sample.

RUNOFF AND SOIL CHARACTERISTICS

Runoff from seven plots sprayed with various volumes of effluent contained more $\text{NH}_3\text{-N}$ than the effluent which infiltrated the soil. A schematic of a typical plot showing the outlay of materials and means of collecting runoff after applications of treatments is presented in Figure 2.

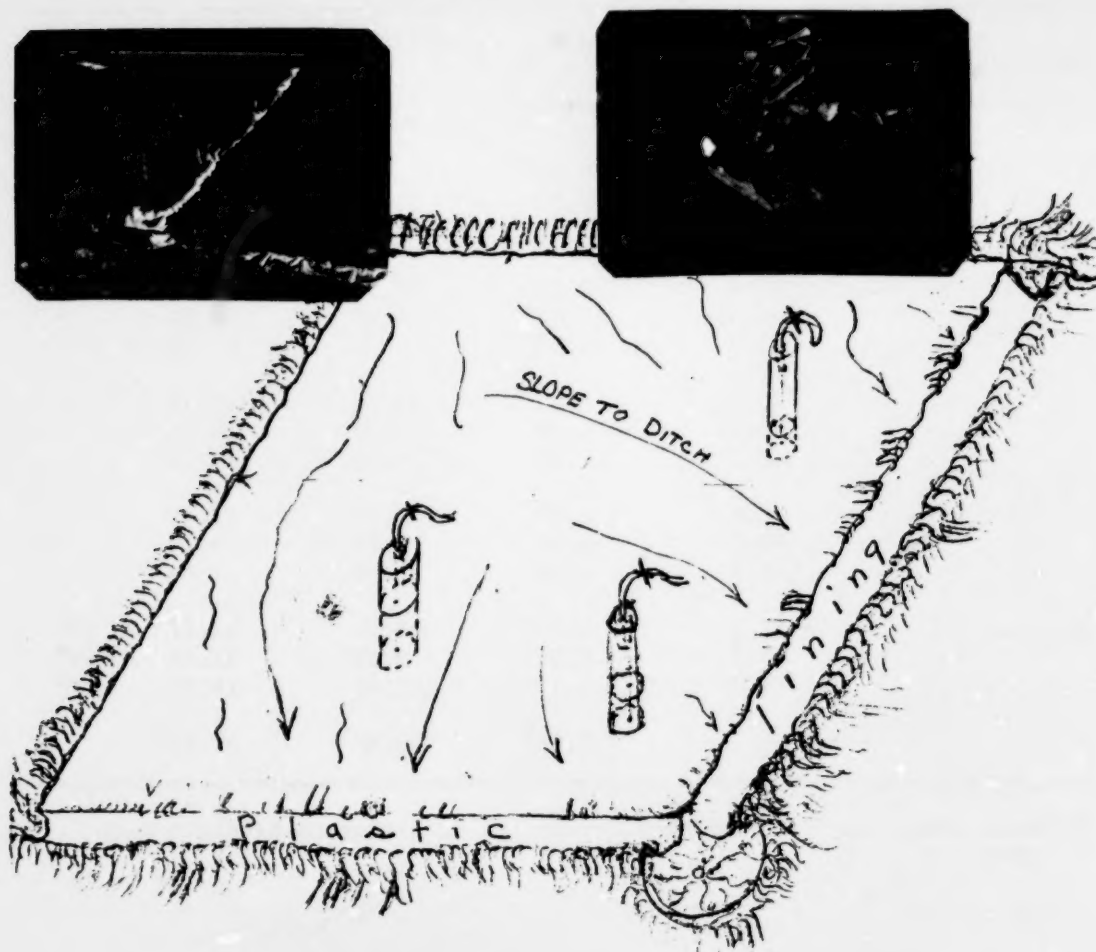


Figure 2. Schematic of a typical 6 x 6 m plot showing arrangement of soil water samplers and runoff materials (Insets show details.)

Samples were taken 24 days after the application of effluent commenced. Negative values of $\text{NH}_3\text{-N}$ concentration in Table 21 mean that the $\text{NH}_3\text{-N}$ concentration of the treatments was reduced by that amount after spraying overland.

TABLE 21. CHANGE IN $\text{NH}_3\text{-N}$ CONCENTRATION IN RUNOFF FROM VOLUMES OF AEROBIC EFFLUENT SPRAYED OVERLAND

Replication	Treatment		
	A	B	C
	mg/l		
1	3.66	6.25	-10.90
2	1.50	-00.50	25.35
3	1.25	- 3.74	18.85
4	1.25	- 6.25	10.35
Average	1.91	- 4.19	10.91

Values in Table 22 were also tabulated from the results of samples collected after an application of treatments was made on the 24th day of this trial period. Runoff is from the 24th day application only. At this particular time of application, the $\text{NO}_3\text{-N}$ concentration was decreased in replications receiving tap water or 100 percent effluent. Runoff was less from plots receiving treatments B and C containing liquid swine manure. This was partly due to the density of vegetable plants; also, the liquid treatment containing 100 percent aerobic effluent is more concentrated with organic and inorganic solubles that abate erosion and enhance soil retention (25). Treatment C was a substantial contribution to soil improvement, giving it a porous, crumbly texture, whereas the soil in plots receiving only tap water was more impervious and resisted infiltration of this liquid.

Soil receiving treatments B and C was darker after daily application of effluent. It was difficult to obtain runoff from plots that received 100 percent aerobic effluent; therefore, the higher concentration of $\text{NH}_3\text{-N}$ in runoff from these plots compared to the other plots should not imply that the total amount of NH_3N loss by this route was high.

TABLE 22. CHANGE IN NITRATE NITROGEN CONCENTRATION IN RUNOFF FROM VARIOUS VOLUMES OF AEROBIC EFFLUENT SPRAYED OVERLAND

Replication	Treatment		
	A	B	C
	mg/l		
1	-0.75	-7.42	-0.09
2	-4.40	1.32	-0.41
3	-0.88	0.44	1.32
4	0.88	-0.88	1.32
Average	-1.29	2.07	0.53

IMPORTANCE OF TIMING EFFLUENT APPLICATION

Suppressed weed growth and a good stand of vegetables were obtained by withholding daily application of effluent until the plants had a good start on the weeds. Two to three weeks was generally sufficient. Vegetable growth was very slow on the plots that received tap water and weed control was difficult. Vegetable growth was very rapid on plots sprayed with effluent, and weed growth was slow.

Application of liquid manure was terminated one to four weeks before time for gathering the vegetables. Variety was a determining factor. Termination of application of effluent hastened fruiting and ripening, whereas on plots sprayed with tap water fruiting was negligible and ripening was premature.

SECTION VIII

TRIAL 3--PERIOD 4

The third application of swine waste was sprayed morning and afternoon--6 days each week from June 13 through July 30, 1977. Ground moisture was recorded as 12 on the tensiometer at the start of treatments. A good stand of vegetable plants consisting of tomatoes, cucumbers, collards, okra, cantaloupes, and peas was in all plots with the exception of those that had been sprayed with water only. On these plots the stand of vegetable plants was scant. Each kind of vegetable was planted in the same amount on all plots. Applications of swine waste during this trial were on the same plots as Trials 1 and 2. There was a lapse of 278 days between Trials 2 and 3. The contents of treatments A, B, and C used for Trial 3 are given in Table 23.

TABLE 23. ANALYSES OF TREATMENTS A, B AND C USED AS IRRIGATION SPRAY ON PLOTS AND FIELDS

Parameter	Treatment		
	A	B	C
Chloride, (mg/l)	10.00	20.00	20.00
NO ₃ -N, (mg/l)	2.20	2.20	2.20
NO ₂ -N, (mg/l)	0.01	0.02	0.03
NH ₃ -N, (mg/l)	0.00	13.00	33.55
BOD, (mg/l)	0.00	40.00	110.00
Specific Cond., (Micromhos/cm)	330.00	520.00	690.00
pH	8.20	8.50	8.00
Coliform, (colonies/100 ml)	0.00	2500.00	2700.00

RUNOFF ANALYSES

Tables 24 through 27 give a measurement of pH, chloride, NH₃-N, and NO₃-N in the runoff from the three treatments applied during this trial.

The data in Table 24 shows that replications receiving water only displayed an overall increase in $\text{NH}_3\text{-N}$ content in the runoff.

TABLE 24. CHANGE IN AMMONIA-NITROGEN CONTENT OF VARIOUS VOLUMES OF AEROBIC EFFLUENT AS MEASURED IN PLOT RUNOFF

Replication	Treatment		
	A	B	C
	mg/l		
1	0.83	2.25	-13.42
2	0.46	3.85	----
3	1.22	----	-18.30
4	1.04	3.85	-13.42
Average	0.89	3.31	-15.04

----No sample.

The same observation may be noted for three out of four replications receiving a mixture of 50 percent effluent and 50 percent tap water. The exact opposite was observed in the data from plots treated with 100 percent effluent. The $\text{NH}_3\text{-N}$ content of the runoff was reduced by almost one-half. These effects reflect differences in plant density among the plots. Plots substantially reducing $\text{NH}_3\text{-N}$ had a heavier growth of plant material and the rate of runoff was slow.

Table 25 shows changes in pH of runoff. In replications sprayed with water, the overall effect was essentially no change in pH. Runoff from plots receiving the effluent and water mixture yielded a decrease in pH. Areas receiving pure effluent showed practically no change in pH due to overland flow of this treatment after spraying.

It is possible that these irregularities in pH in the runoff reflect different degrees of nitrification in the ground surface among these plots (26).

The changes in $\text{NO}_3\text{-N}$ are given in Table 26. Runoff samples from replications receiving water only exhibited both increase and decrease in $\text{NO}_3\text{-N}$ measurements with two plots having identical increase and the other two plots showing identical decrease in $\text{NO}_3\text{-N}$. In samples from plots receiving treatment B, $\text{NO}_3\text{-N}$ content varied from one replication to another with two plots showing no change and the remaining two showing an increase and a decrease.

TABLE 25. CHANGE IN pH OF VARIOUS VOLUMES OF AEROBIC EFFLUENT AS MEASURED IN PLOT RUNOFF

Replication	Treatments		
	A	B	C
	change in pH units		
1	0.30	-0.50	-0.10
2	0.30	-0.50	0.00
3	-0.40	-0.90	0.00
4	-0.20	0.60	0.00
Average	0.00	-0.30	-0.02

TABLE 26. CHANGE IN NITRATE NITROGEN CONTENT OF VARIOUS VOLUMES OF AEROBIC EFFLUENT AS MEASURED IN PLOT RUNOFF

Replication	Treatments		
	A	B	C
	mg/l		
1	1.32	0.00	-0.88
2	1.32	-1.32	0.00
3	-0.44	0.44	-2.20
4	-0.44	0.00	-2.20
Average	0.76	-0.88	-1.32

Sections treated with pure effluent gave a decrease in $\text{NO}_3\text{-N}$ content. When treatment A was applied to the soil, two plots showed an increase in $\text{NO}_3\text{-N}$. On plots receiving treatment C, less $\text{NO}_3\text{-N}$ was present in the runoff from three plots than before the treatment was applied.

There was 0 mg/l (-2.20 mg/l) of $\text{NO}_3\text{-N}$ in samples from two of these plots and 0.88 (-0.88) mg/l less $\text{NO}_3\text{-N}$ in the runoff from one of the three plots. The density of plants on these three plots was high. Wherever lateral movement of water through the upper 15.2 cm of soil into the runoff occurred,

the soil was effective in changing the concentration of treatments, especially so, if the number of plants was high. Similar conditions affect the runoff changes in $\text{NO}_3\text{-N}$ from plots receiving treatment B but less than from plots receiving treatment C. The data in Table 27 show changes in chloride of plots undergoing treatments A, B, and C.

TABLE 27. CHANGE IN CHLORIDE CONTENT OF VARIOUS VOLUMES OF AEROBIC EFFLUENT AS MEASURED IN PLOT RUNOFF

Replication	Treatment		
	A	B	C
	mg/l		
1	5.0	0.0	5.0
2	5.0	0.0	0.0
3	5.0	5.0	5.0
4	10.0	0.0	5.0
Average	6.2	1.2	3.7

Samples from areas treated with tap water only and also those treated with 100 percent effluent showed a definite increase in chloride content, while runoff samples from replications having treatment B applied to them remained practically unchanged.

SOIL WATER ANALYSES

After applications of the treatments were made during Trial 3, pH reduction in soil water was greatest at the 15.2 cm depth for treatments A and B and very near the same at all depths for treatment C. Groups of microorganisms, having the capacity to degrade soil nutrients, reach large numbers in the surface of agricultural soils (28). These microorganisms are agents for denitrification, a process believed to raise pH (26). Evidence of nitrification (Table 28) at the 15.2 cm depth is more apparent, especially so for treatment B at the 15.2 cm depth, thus casting some doubt on the denitrification and the increased pH hypothesis, as there was an apparent greater reduction in pH at the 30.5 cm depth for treatment B. Nitrification was evident in Trial 3, so speculation that denitrification contributed to low mean nitrate production at all depths may be in order. There was a mean reduction of 22 percent for pH over all treatments (Table 26). There is more evidence for than against the denitrification - increased pH hypothesis in this trial. Denitrification usually occurs in situations where there is overflowing of land by irrigation (28), but it is temporary and nitrification is soon restored after the land is no longer saturated.

TABLE 28. DECREASE IN pH OF VARIOUS VOLUMES OF AEROBIC EFFLUENT SPRAYED OVERLAND AS MEASURED IN SOIL WATER AT DIFFERENT DEPTHS

Replication	Depth (cm)	Treatments			
		A	B	C	
pH unit decrease					
1	15.2	3.10	2.40	2.20	
	30.5	3.10	2.80	2.70	
	45.7	3.00	3.10	2.90	
2	15.2	2.20	2.40	2.00	
	30.5	1.95	2.50	2.00	
	45.7	2.50	2.20	1.80	
3	15.2	0.60	0.95	0.80	
	30.5	0.60	2.60	0.80	
	45.7	0.50	1.40	0.80	
4	15.2	0.30	2.50	1.50	
	30.5	0.70	1.50	0.60	
	45.7	2.20	0.95	0.60	
Mean Values	15.2	1.55	2.06	1.62	1.74 ^a
	30.5	1.58	2.35	1.52	1.81 ^a
	45.7	2.05	1.19	1.52	1.82 ^a
		1.72 ^a	2.10 ^a	1.55 ^a	

^aMean values followed by a common letter are similar as determined by DNMR (P < .01).

The $\text{NH}_3\text{-N}$ content of treatments B and C used during Trial 3 was near half that used for Trial 2. As expected, the percent reduction of $\text{NH}_3\text{-N}$ was 98 to 99 percent of the $\text{NH}_3\text{-N}$ in treatments B and C, respectively. $\text{NH}_3\text{-N}$ was transported downward through the soil by water with apparently very little transformation occurring along with movement, and, consequently, uniform concentration of $\text{NH}_3\text{-N}$ at each depth. A standard deviation of ± 0.0914 mg/l for $\text{NH}_3\text{-N}$ changes suggest uniformity of data within the treatments (Table 29).

The data in Table 30 shows considerable variation among the plots, with most of the highest $\text{NO}_3\text{-N}$ values in plots receiving aerobic effluent appearing at the 15.2 cm depth. $\text{NO}_3\text{-N}$ was either generated (at most depths) or it remained the same in the treatment percolate as it was in the treatments. It was considered that a substantial portion of the generated nitrate nitrogen would be utilized by the vegetable crops during the remaining growing season and returned to the soil by unused vegetation.

TABLE 29. DECREASE IN $\text{NH}_3\text{-N}$ CONTENT OF VARIOUS VOLUMES OF AEROBIC EFFLUENT AS MEASURED IN SOIL WATER AT DIFFERENT DEPTHS

Replication	Depth (cm)	Treatment			
		A	B	C	
		mg/l			
1	15.2	-0-	13.00	33.49	
	30.5	-0-	13.00	33.49	
	45.7	-0-	13.00	33.49	
2	15.2	-0-	12.66	33.37	
	30.5	-0-	12.94	33.37	
	45.7	-0-	13.00	33.55	
3	15.2	-0-	12.63	33.55	
	30.5	-0-	12.81	33.55	
	45.7	-0-	12.75	33.55	
4	15.2	-0-	12.76	32.46	
	30.5	-0-	12.63	33.19	
	45.7	-0-	12.56	33.31	
Mean Values	15.2	-0-	12.76	33.21	15.32 ^a
	30.5	-0-	12.84	33.40	15.41 ^a
	45.7	-0-	12.83	33.47	15.43 ^a
		-0-	12.81 ^b	33.36 ^c	

^{a,b,c} Mean values not followed by a common letter differ as determined by DNMRT ($P < .01$).

Differences between post treatment soil water values for chloride concentration and treatment concentration of chloride ions are given in (Table 31). The chloride ion concentration of soil water had a range of 10 mg/l (0 mg/l change) to 77 mg/l (57 mg/l change). A portion of the chloride ions that was added to the plots by the treatments adhered to the soil. Uptake by the plants removed a portion, also. Pretreatment (Trial 3) analysis of the soil in all plots for chloride ions gave a concentration of less than 25 parts per million (ppm). High concentrations of chloride ions in the soil water after treatment are due to the accumulation of chloride ions during Trial 3. The decreases in specific conductance shown in Table 32 imply an uptake of salts in the treatments by the soil and plants. Analyses of the soil prior to Trial 3 gave a range of 150 to 1000 ppm of calcium among the plot depths. Analysis of the soil was not conducted for post treatment contents.

TABLE 30. CHANGE IN NO₃-N CONTENT OF VARIOUS VOLUMES OF AEROBIC EFFLUENT AS MEASURED IN SOIL WATER

Replication	Depth (cm)	Treatment		
		A	B	C
		mg/l		
1	15.2	0.00	41.80	8.80
	30.5	0.00	17.60	0.00
	45.7	5.28	8.80	0.88
2	15.2	1.76	1.76	11.00
	30.5	0.00	0.00	30.00
	45.7	0.44	0.00	33.00
3	15.2	-0.44	26.84	8.80
	30.5	-0.44	2.20	1.32
	45.7	1.32	8.80	1.32
4	15.2	0.00	6.60	0.00
	30.5	2.20	1.30	2.20
	45.7	1.32	2.20	2.20
Mean Values	15.2	0.33	19.25	7.15 8.91 ^a
	30.5	0.44	5.27	8.38 4.69 ^a
	45.7	2.09	4.95	9.35 5.46 ^a
		0.95 ^a	9.82 ^b	8.29 ^b

^{a,b}Mean values not followed by a common letter differ as determined by DNMRT (P < .05).

TABLE 31. CHANGE IN CHLORIDE CONTENT OF TREATMENTS SPRAYED OVERLAND AS MEASURED IN SOIL WATER AT DIFFERENT DEPTHS

Replication	Depth (cm)	Treatments			
		A	B	C	
		mg/l			
1	15.2	20.00	-0-	40.00	
	30.5	10.00	-0-	35.00	
	45.7	25.00	5.00	57.00	
2	15.2	15.00	10.00	-0-	
	30.5	17.00	51.00	-0-	
	45.7	15.00	51.00	10.00	
3	15.2	25.00	8.00	30.00	
	30.5	13.00	3.00	15.00	
	45.7	20.00	5.00	35.00	
4	15.2	10.00	5.00	55.00	
	30.5	10.00	5.00	25.00	
	45.7	10.00	5.00	25.00	
Mean Values	15.2	17.5	5.7	31.5	18.2 ^a
	30.5	12.5	14.7	18.5	15.2 ^a
	45.7	17.5	16.5	31.7	21.9 ^a
		15.8 ^a	12.3 ^a	27.2 ^a	

^aMean values followed by a common letter are similar as determined by DNMR, ($P < .05$).

TABLE 32. DECREASE IN SPECIFIC CONDUCTANCE OF TREATMENTS AS MEASURED IN SOIL WATER AT DIFFERENT DEPTHS

Replication	Depth (cm)	Treatment			
		A	B	C	
		µmhos/cm			
1	15.2	190	220	415	
	30.5	195	270	440	
	45.7	215	245	440	
2	15.2	230	365	515	
	30.5	223	220	506	
	45.7	218	190	390	
3	15.2	228	245	390	
	30.5	226	270	532	
	45.7	180	410	440	
4	15.2	220	383	550	
	30.5	221	380	525	
	45.7	240	370	540	
Mean Values	15.2	217	303	467	329 ^a
	30.5	216	285	500	333 ^a
	45.7	213	303	452	322 ^a
		215 ^a	297 ^a	473 ^b	

^{a, b} Mean values not followed by a common letter differ as determined by DNMR (P < .01).

SECTION IX

SUMMARY: PERIODS 1, 2, 3, AND 4

PERIOD 1

Analyses of demonstration fields numbered 1, 2, and 3 were made after one, two, and three hours, respectively, of spraying (1.96 cm/hr) with 100 percent aerobic effluent. The analyses indicated that the soil-plant response to aerobic effluent was immediate for pH, chloride ions, $\text{NO}_3\text{-N}$, etc., at a depth of 91 cm.

The pretreatment period findings indicated uniformity in soil contents among the experimental plots, with standard deviations of ± 0.19 for pH and ± 0.67 ppm for chloride ion concentration among samples. The plots were, therefore, assigned treatments A, B, and C in a completely random design.

PERIODS 2, 3, AND 4

There was no significant difference ($P < .05$) in percolation of treatments among depths for Trials 1 and 3, but there was significantly less ($P < .01$) chloride ion concentration at the 45.7 cm depth compared to successively lesser depths for Trial 2. In all trials, as in a similar investigation (29), the concentration of chloride ions at each depth was an indication of the extent of percolation of the treatments through the soil.

The fate of applied nitrogen was one of the principal concerns in this study. Decreases in $\text{NH}_3\text{-N}$ after application of the second and third levels of effluent were very similar for Trials 1, 2, and 3, although the total volumes for successive trials were increased. The reduction of $\text{NH}_3\text{-N}$ in treatments B and C was more than 97 percent after all applications. The nitrification process produced nitrate, the preferred form of nitrogen for plant growth (3), from $\text{NH}_3\text{-N}$, the form of nitrogen that is found in defecated swine waste in addition to organic nitrogen (26). Because of the extent of the nitrification process in these trials, the results impose recognizable limitations, but trends in mg/l change of $\text{NH}_3\text{-N}$ have been established that were associated with the volume of swine effluent applied to land for vegetable crop production.

Summaries of $\text{NH}_3\text{-N}$ transformation and $\text{NO}_3\text{-N}$ generation and utilization after spraying plots planted with vegetable crops are given in Appendix Tables A-1 and A-2. $\text{NH}_3\text{-N}$ transformation and $\text{NO}_3\text{-N}$ generation and utilization were plotted against the amount of $\text{NH}_3\text{-N}$ in all treatments for the combined

trials (Figure 3). The curve for $\text{NH}_3\text{-N}$ concentration in treatments and the $\text{NH}_3\text{-N}$ change after treatments is almost linear, suggesting that ammonia nitrogen and inorganic nitrogen were almost completely transformed to $\text{NO}_3\text{-N}$, a considerable portion of which was presumed to have been utilized by the plants, and some denitrified. Since only the fruit from the vegetable plants was removed, some of the assimilated nitrogen was returned to the soil and degraded by microorganisms.

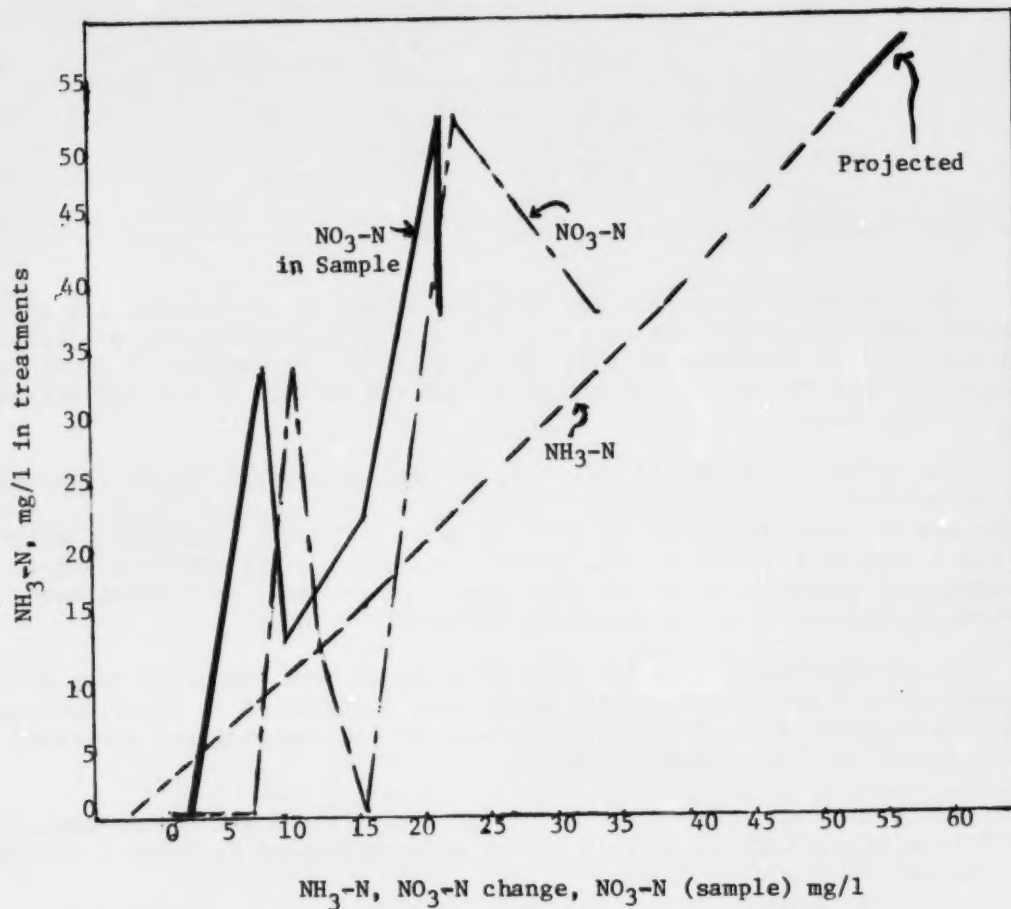


Figure 3. Ammonia nitrogen concentration of treatments applied to the soil and change in ammonia and nitrate nitrogen as measured in soil water.

The soil had the capacity to adjust pH to very near the same values in soil water, especially in Trials 2 and 3 (Table 33). The buffering action of the soil limits change in soil pH, and after a period of time there should be more change (30), even in the pH of the soil water. The specific conductance measured in Trial 3 was considerably lower after all treatments.

TABLE 33. SUMMARY OF pH VALUES OF SOIL WATER AFTER TRIALS 1, 2, AND 3

Trials	Treatments		
	A	B	C
	pH		
1	6.90	not rec.	5.95
2	6.10	6.08	5.87
3	6.48	6.40	6.45

The volume of runoff was not measured in any of the trials, but it varied among the plots from approximately 0.5 to 4.0 liters per application during Trial 1, and somewhat more during Trial 3. The volume of runoff was dependent upon the density of the plant and the percent of aerobic effluent in the treatment.

The uptake of $\text{NO}_3\text{-N}$ and chlorides in vegetable plant leaves (composite of three samples) did not exceed acceptable standards after Trial 3. The response of vegetable crops was good in plots receiving treatment C after Trial 1, and in plots receiving treatments B and C after Trials 2 and 3, the response of vegetable crops was very good. It was easy to control weeds and obnoxious grasses in plots receiving treatments B and C.

It was considered possible that if analyses were conducted four to six months after Trials 2 and 3, time would have contributed to the accumulation of more $\text{NO}_3\text{-N}$ as after Trial 1, especially if low temperatures prevailed (24) during the post growing season.

There was a greater change in pH for treatments B and C when compared with treatment A for all trials, except after treatment C, Trial 3 (Tables 8, 14, and 28).

In addition to good growth of vegetable plants on the experimental plots, good stands of grass and clover mixtures were obtained in early fall of 1976 and 1977, as shown in Figure 4.



Figure 4. Portion of pasture showing section where grass-clover mixture gave good growth. Aerobic effluent was the only source of nutrients in 1977.

Aerobic effluent was applied quite heavily during the summer of 1977, and again shortly after the rye-oat-subterranean clover mixture was planted in September. The liquid spray was as good for its moisture as for its nutrients.

Figure 5 shows an even better stand of a rye-oat-subterranean clover mixture planted on bermuda grass, disked and irrigated with aerobic effluent.

The lush growths of grasses and legumes as well as vegetable crops which can be obtained in all seasons by utilizing the transformed anaerobic and aerobic constituents of animal waste may well acquire far-reaching significance in systems of animal production.



Figure 5. A very good stand of winter grazing for feeder pigs -
sprayed with aerobic effluent.

SECTION X

EXHIBITS

Figures 6 through 12 are monthly concentrations of inputs to the anaerobic lagoon against outputs from the aerobic lagoon to the forest area and for overland spray of demonstration fields, plots and pasture areas.

Figures 13 and 14 are summaries of the monthly swine population of the farrowing area that provided influent to lagoons and monthly BOD₅ analysis of the lagoons.

Figure 6 shows data for pH of both lagoons to be somewhat inconsistent throughout the year of 1976. The pH varied from 7.3 to 8.8 in the first lagoon and from 6.6 to 7.4 in the second lagoon. These pH values were favorable for methane production and indicative of moderate loading.

Ammonia nitrogen in the first lagoon (Figure 7) was considerably higher than in the second lagoon during the early summer months. So the first lagoon was a better source of waste water from which the plant nutrients for overland spray might have been obtained. This finding is consistent with data from work conducted at Ohio State University (31). Seasonal variation of ammonia nitrogen was less pronounced in the second lagoon than in the first lagoon.

Data for nitrate nitrogen given in Figure 8 show only slight difference in this parameter as effluent passes from the first to the second lagoon. NO₃-N concentration in the lagoons was considerably below the level of acceptable water quality throughout most of the year, but far exceeded these limits in soil water where overland spray was applied. Nitrite nitrogen was found in the anaerobic lagoon in November and December in very small amounts. Figure 9 shows that there was a range of 0 to 0.68 mg/l of nitrite nitrogen in the aerobic lagoon. The chloride concentration was important because of its effect on the taste of water. Data for chloride concentration shown in Figure 10 were well below acceptable water standards throughout 1976.

Conductivity data given in Figure 11 showed a larger decrease during the warm seasons after degraded anaerobic effluent passed into the second lagoon. Conductivity was highest in the hot weather months in the first lagoon. There was an increase in conductivity in the second lagoon for the cooler months in 1976. The data in Figure 11 indicate that monthly changes in aerobic lagoon effluent coincided with monthly changes in anaerobic lagoon

effluent. Monthly concentration of BOD_5 (Figure 12) also coincided rather closely with swine population (Figure 13 and 14), indicating that loading rate affected BOD_5 concentration in the lagoons.

Data in Appendix Tables A-3 through A-8 document the percent reduction in pH, BOD_5 , specific conductance, coliform bacteria, chloride and NO_3-N . The pH was increased after the waste was transported to the second cell. Nitrite and BOD_5 was substantially decreased in the second lagoon because of the moderate input of defecated waste to the lagoon (5). The data presented in Appendix Tables A-1 and A-2 is the treatment mean summary of transformation changes of NH_3-N and use of NO_3-N during Trials 1, 2, and 3. Appendix Tables A-9 and A-10 show the soil concentration of nitrate nitrogen and chloride after spraying in Trial 3.

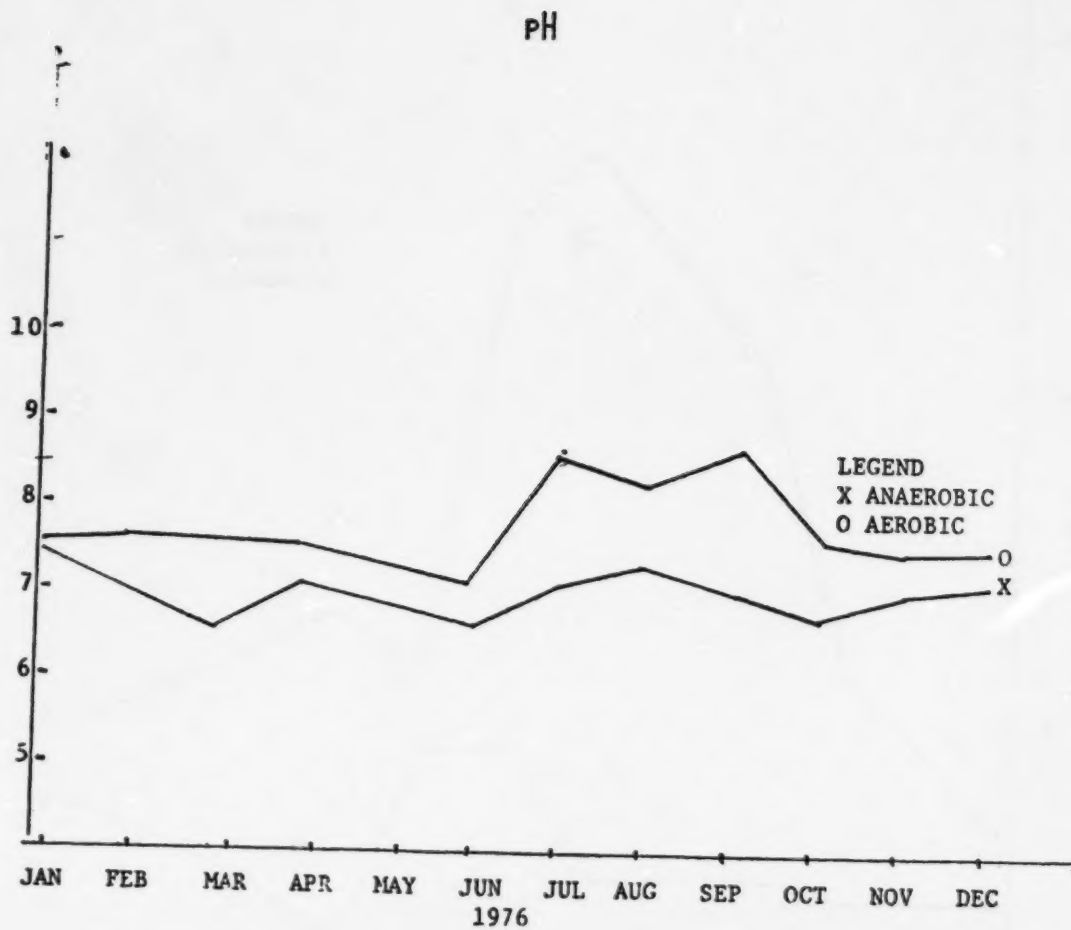


Figure 6: Monthly pH analyses of lagoons containing swine waste.

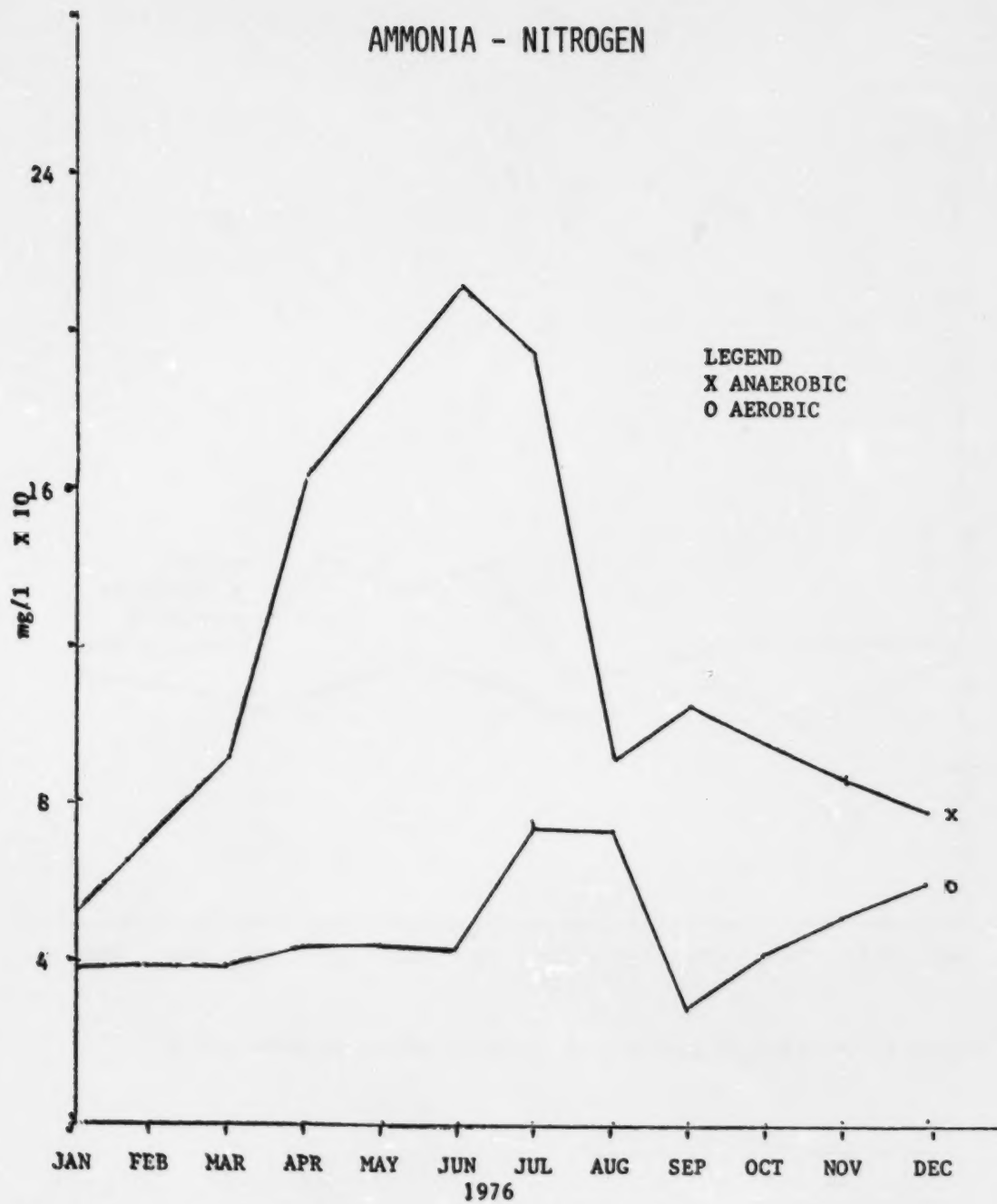


Figure 7. Monthly ammonia analyses of lagoons containing swine waste.

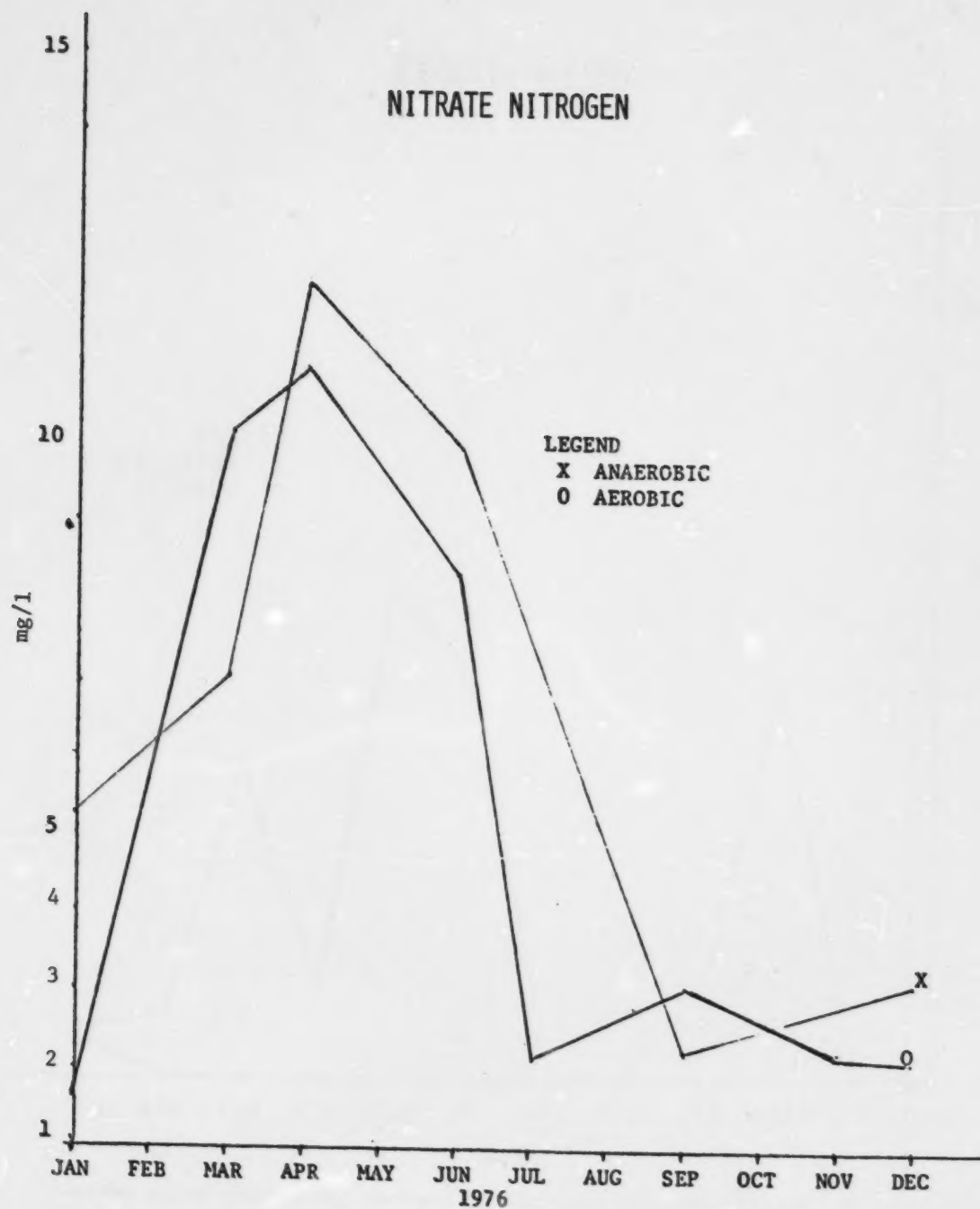


Figure 8. Monthly nitrate analyses of lagoons containing swine waste.

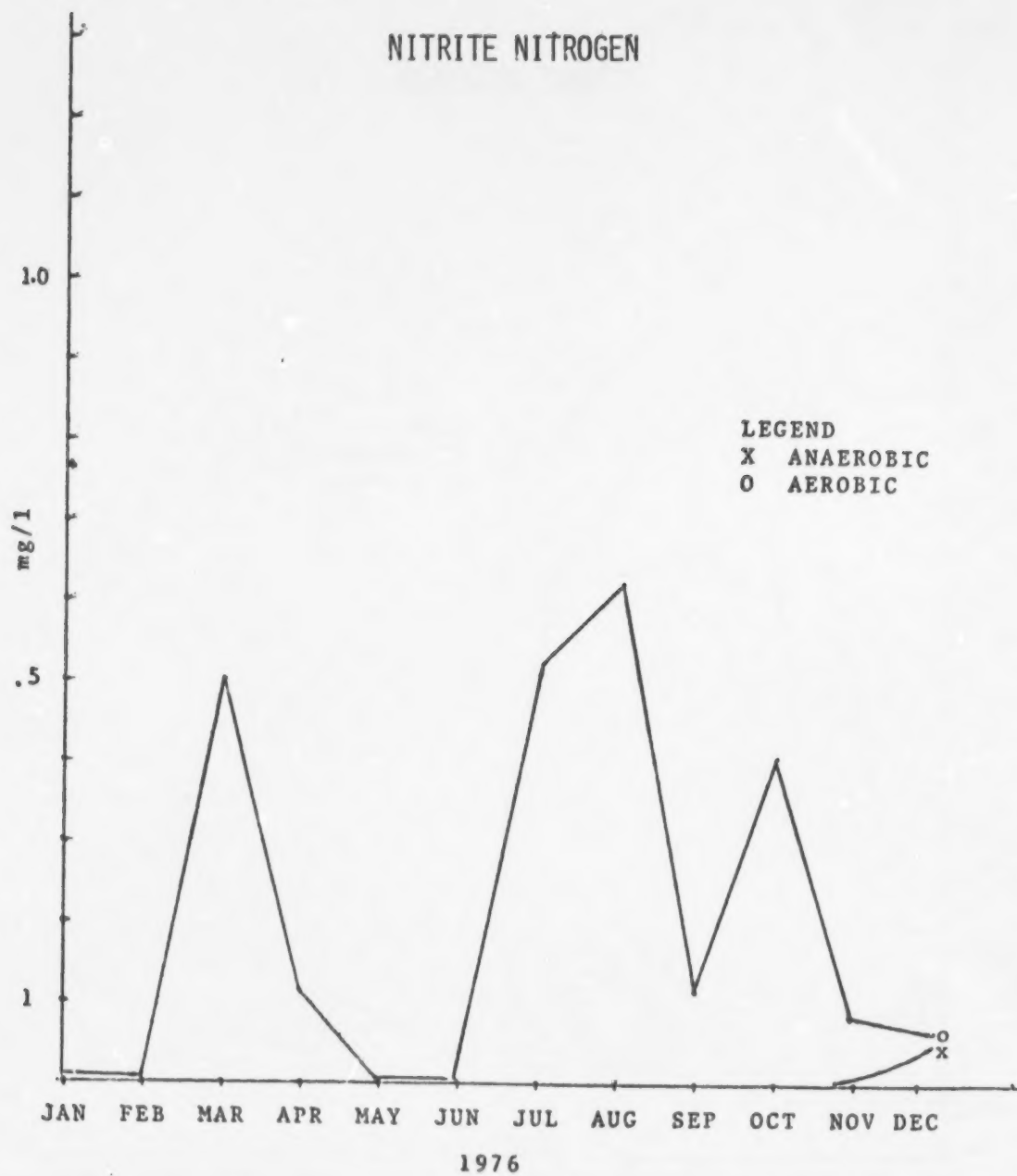


Figure 9. Monthly nitrite analyses of lagoons containing swine waste.

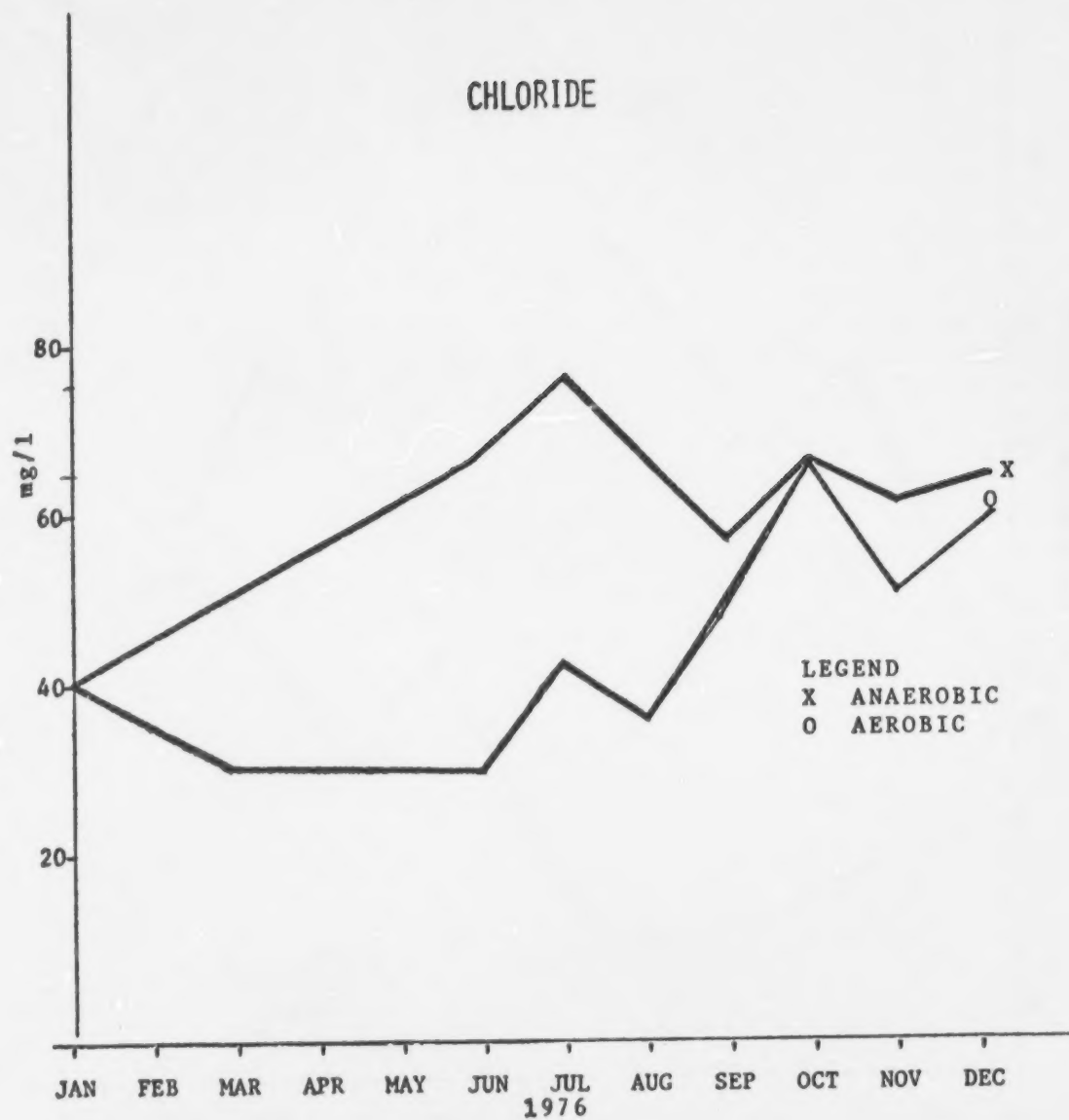


Figure 10. Monthly chloride analyses of lagoons containing swine waste.

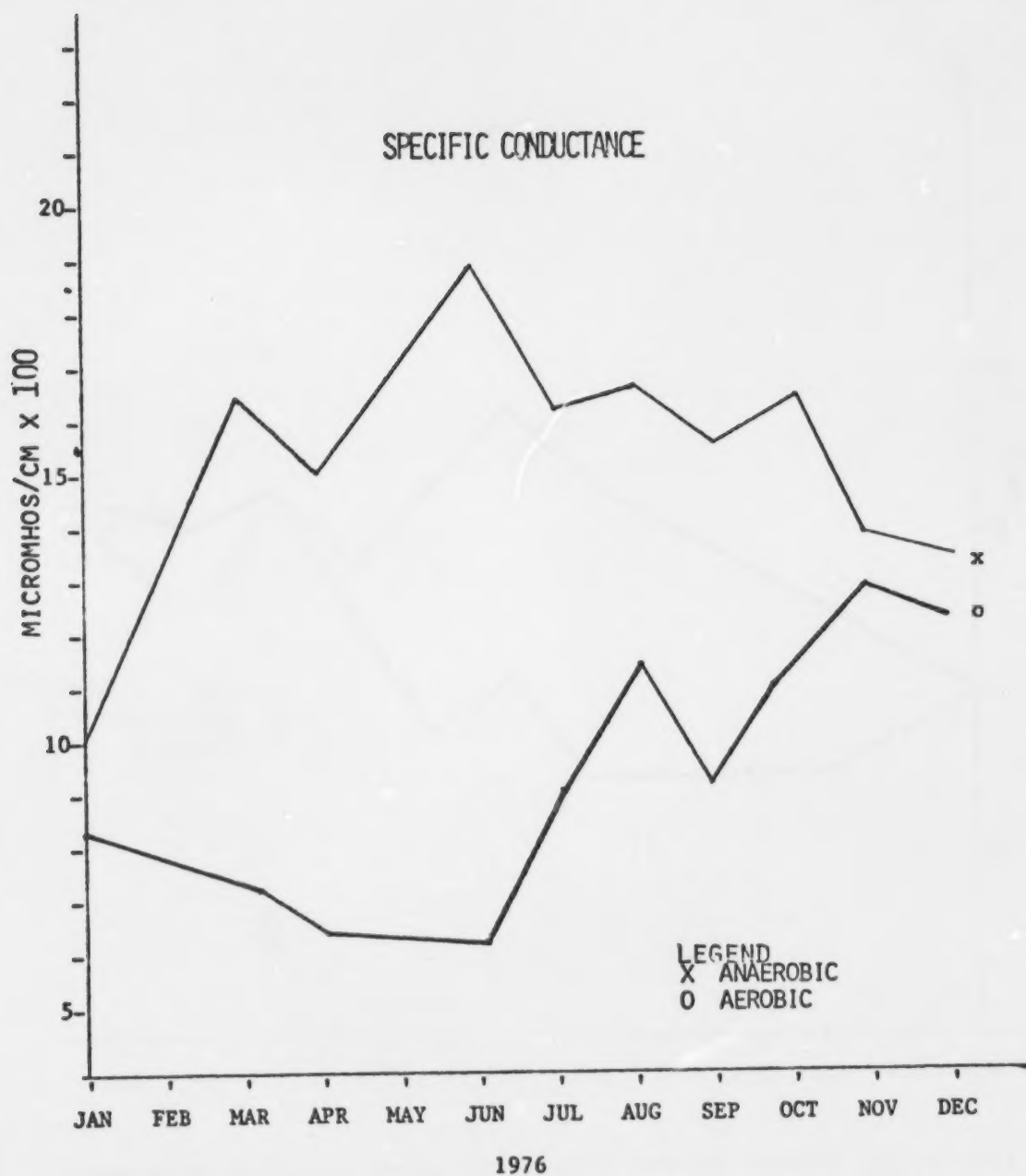


Figure 11. Monthly specific conductance analyses of lagoons containing swine waste.

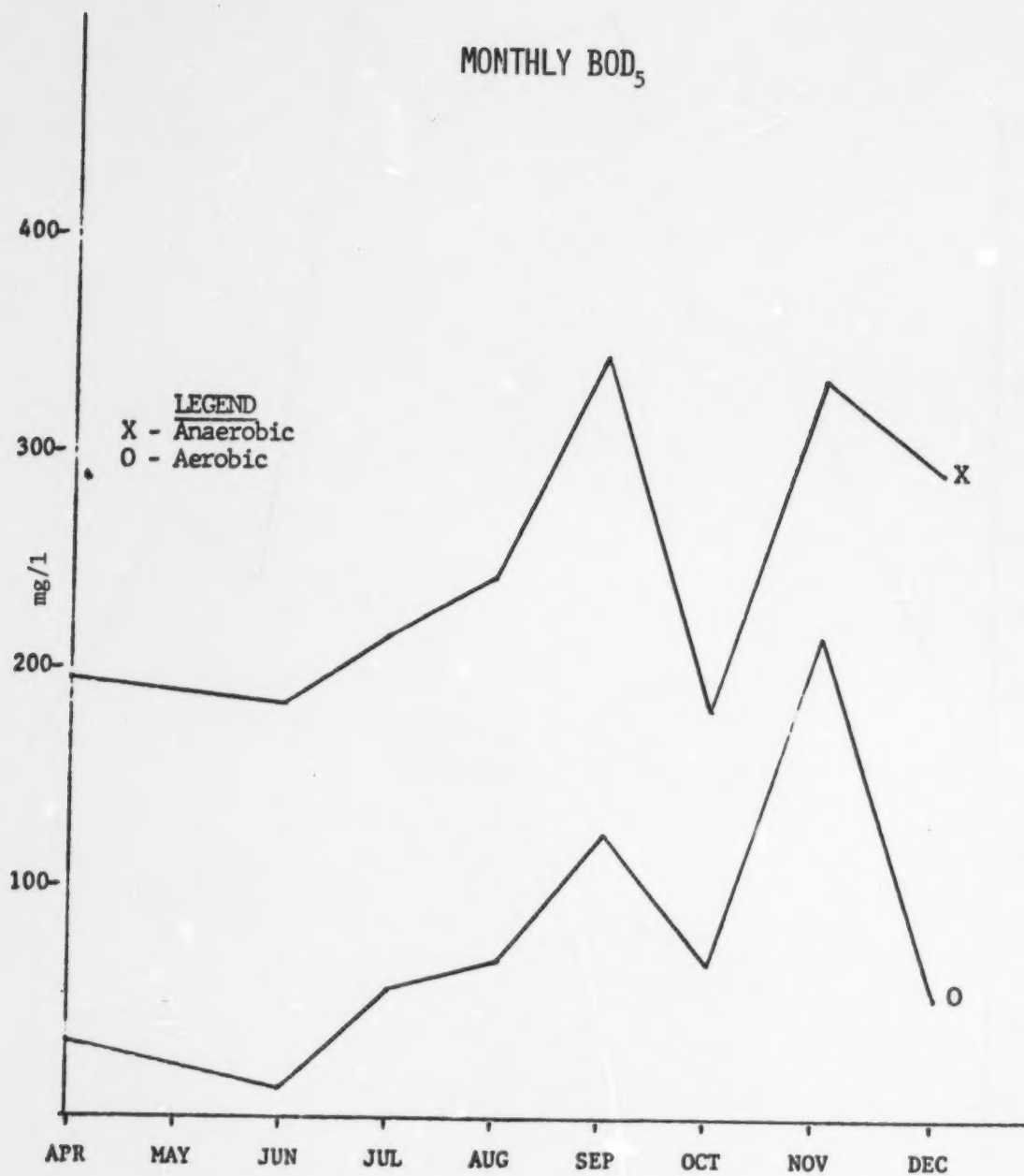


Figure 12. Monthly BOD₅ analyses of lagoons containing swine waste.
1976

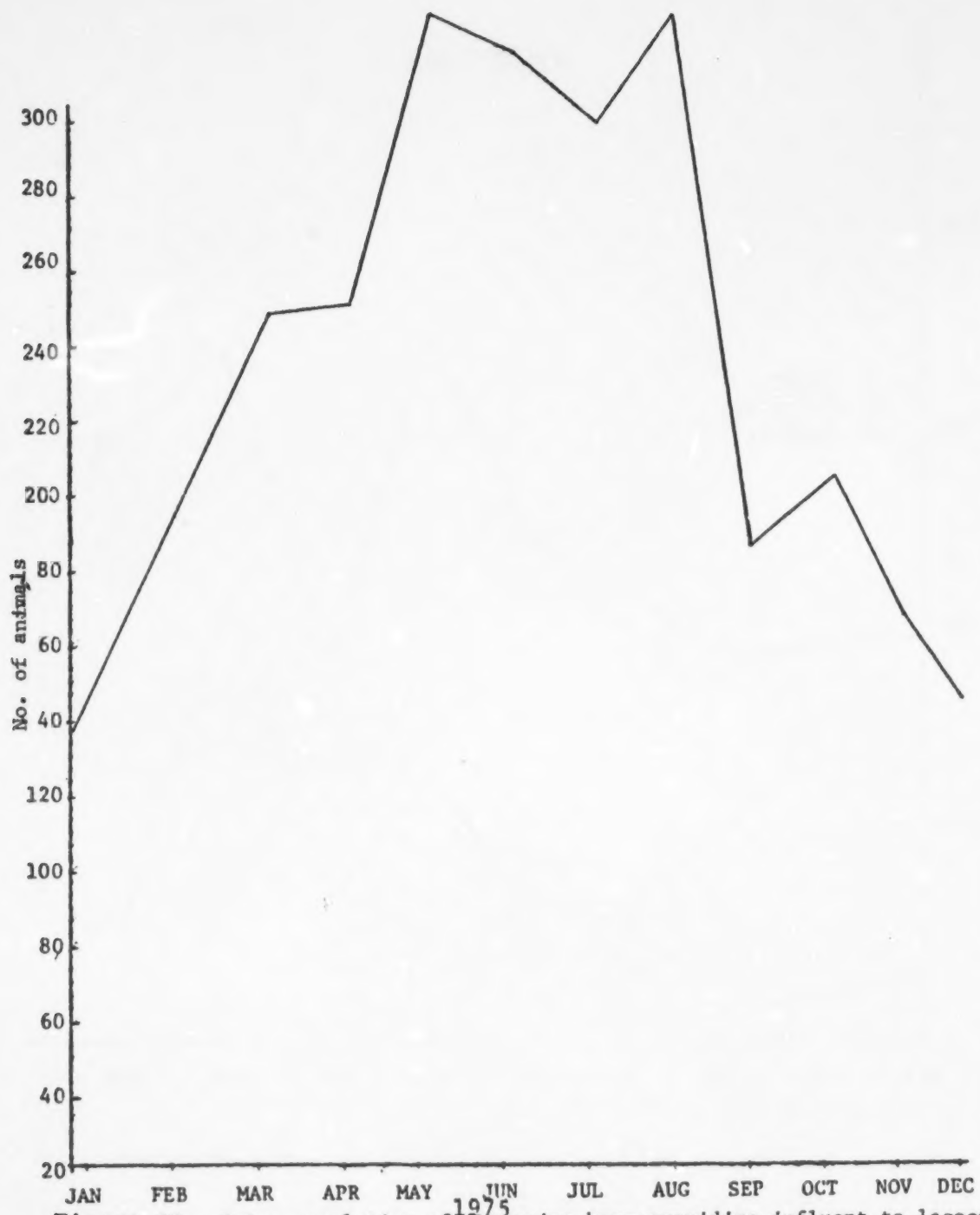


Figure 13. Swine population of farrowing barn providing influent to lagoon.

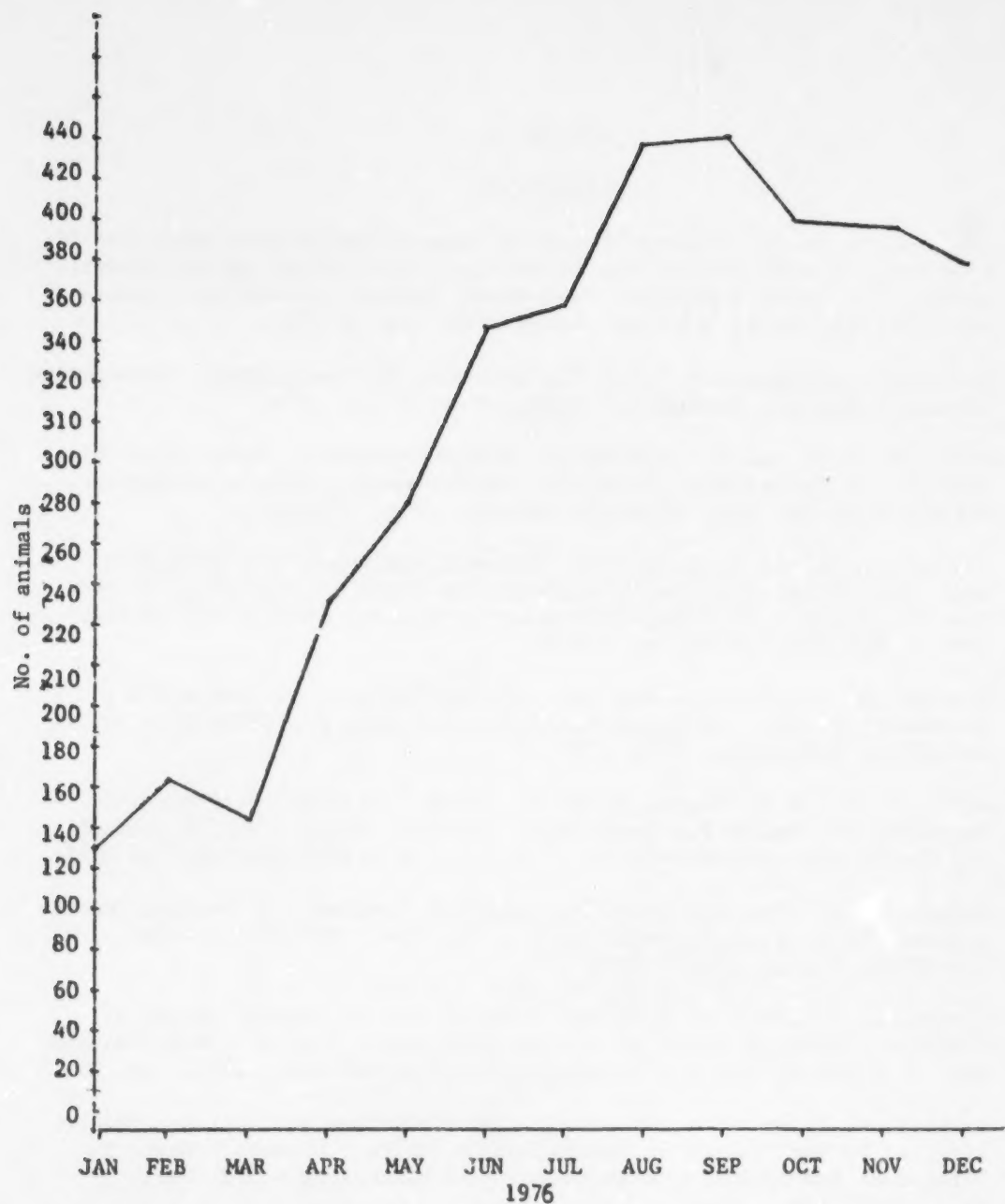


Figure 14. Swine population of farrowing barn providing influent to lagoon.

SECTION XI

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SECTION XII

PUBLICATIONS ASSOCIATED WITH PROJECT RESULTS

Grier, H. E., W. Burton and S. C. Tiwari. Overland Recycling of Animal Waste, Proceedings of the 1976 Cornell Agricultural Waste Management Conference. Ann Arbor Science Publishers, Inc., Ann Arbor, Mich., pp. 693-702.

Grier, H. E., G. C. Gupta and W. Burton. Salt Removal Efficiencies on Land Disposal of Swine Waste. Journal of Environmental Engineers. Vol. 130, No. 4, 1977, pp. 551-556.

APPENDIX A

LIST OF APPENDIX TABLES

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TABLE A-1. SUMMARY OF MEAN $\text{NH}_3\text{-N}$ UTILIZATION AFTER APPLICATION OF EFFLUENT TO PLOTS

Experiments		Treatments		
		A	B	C
TRIAL 1, Volume, cm	7.6			
$\text{NH}_3\text{-N}$, mg/l, applied		0.00	15.87*	38.75
change		0.03 ^a	-15.60*b	-38.43 ^e
TRIAL 2, Volume, cm	18.3			
$\text{NH}_3\text{-N}$, mg/l, applied		0.00	22.50	52.09
change		0.00 ^a	-22.25 ^c	-51.61 ^f
TRIAL 3, Volume, cm	36.6			
$\text{NH}_3\text{-N}$, mg/l, applied		0.00	13.00	33.55
change		0.00 ^a	-12.81 ^d	-33.36 ^g

abcdefg Means not followed by same letter differ ($P < .01$) according to DNMR.
 *Calculated Values

TABLE A-2. SUMMARY OF MEAN $\text{NO}_3\text{-N}$ GENERATION AFTER APPLICATION OF TREATMENTS TO PLOTS

Experiments				
TRIAL 1, Volume, cm	7.6			
$\text{NO}_3\text{-N}$, mg/l, applied		17.60	-----	12.00
change		- 1.88 ^a	-----	21.61 ^b
in soil water		16.72		33.61
TRIAL 2, Volume, cm	18.3			
$\text{NO}_3\text{-N}$, mg/l, applied		4.40	0.30	0.70
change		2.65 ^{ab}	15.66 ^{ab}	21.67 ^b
in soil water		7.05	15.96	22.37
TRIAL 3, Volume, cm	18.3			
$\text{NO}_3\text{-N}$, mg/l, applied		2.20	2.20	2.20
change		0.95 ^{ab}	9.82 ^{ab}	8.29 ^{ab}
in soil water		3.15	12.02	10.49

----- No analysis.

^{ab} Means not followed by same letter differ ($P < .05$) according to DNMR.

TABLE A-3. MONTHLY ANALYSIS OF pH OF ANAEROBIC AND AEROBIC LAGOONS - 1976

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Analysis												
Anaerobic pH	7.47	-----	6.70	7.10	-----	6.75	7.20	7.35	7.10	6.70	6.94	7.10
Aerobic pH	7.54	-----	7.60	7.60	-----	7.23	8.60	8.50	8.80	7.96	7.45	7.70
Increase	0.07	-----	0.10	0.50	-----	0.48	1.40	1.15	1.70	1.26	1.51	0.61
Increase, %	00.93	-----	01.49	07.00	-----	07.11	19.44	15.65	23.94	18.80	21.76	7.77

TABLE A-4. MONTHLY ANALYSIS OF BOD OF ANAEROBIC AND AEROBIC LAGOONS - 1976

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Analysis												
Anaerobic BOD, mg/l	-----	-----	-----	195	-----	180	210	240	330	180	335	300
Aerobic BOD, mg/l	-----	-----	-----	30	-----	10	50	60	130	60	215	50
Reduction, mg/l	-----	-----	-----	165	-----	170	160	180	200	120	120	250
Reduction, %	-----	-----	-----	84.61	-----	94.44	79.19	75.00	60.60	66.67	35.82	83.33

TABLE A-5. MONTHLY ANALYSIS OF SPECIFIC CONDUCTANCE OF ANAEROBIC AND AEROBIC LAGOONS - 1976

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Analysis												
Anaerobic Spec. Cond., $\mu\text{mhos/cm}$	1000	-----	1650	1500	-----	1880	1620	1660	1550	1650	1380	1350
Aerobic Spec. Cond., $\mu\text{mhos/cm}$	825	-----	728	650	-----	640	900	1140	925	1100	1290	1240
Reduction	275		922	750		940	720	520	635	550	90	110
Reduction, %	27.5	-----	56.1	50.0	-----	50.0	44.4	31.3	40.9	33.3	6.5	8.2

TABLE A-6. MONTHLY ANALYSIS OF COLIFORM BACTERIA OF ANAEROBIC AND AEROBIC LAGOONS - 1976

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Analysis												
Anaerobic Coliform, No.	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Aerobic Coliform, No.	NC	NC	NC	NC	NC	NC	900	NC	1000	6900	1000	10,300
Change	----	----	----	----	----	----	----	----	----	----	----	----
Change %	----	----	----	----	----	----	----	----	----	----	----	----

TABLE A-7. MONTHLY ANALYSIS OF CHLORIDE OF ANAEROBIC AND AEROBIC LAGOONS - 1976

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Analysis Anaerobic Chloride, mg/l	40	45	50	55	60	65	75	65	55	65	60	65
Aerobic Chloride, mg/l	45	30	30	30	30	30	40	35	45	65	50	60
Change, mg/l	5	-15	-20	-25	-30	-35	-35	-30	-10	0	-10	-5
Change, %	12.5	33.3	40.0	45.5	50.0	53.8	60.0	46.7	18.1	----	16.6	7.69

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TABLE A-8. MONTHLY ANALYSIS OF NO₃-N OF ANAEROBIC AND AEROBIC LAGOONS - 1976

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Analysis Anaerobic NO ₃ -N, mg/l	5.28	-----	7.10	14.88	-----	9.68	7.63	5.18	1.32	2.10	2.60	3.00
Aerobic NO ₃ -N, mg/l	1.76	-----	10.28	9.80	-----	8.36	1.32	2.52	2.20	2.10	2.32	2.20
Change, mg/l	-3.52	-----	3.18	-5.08	-----	1.32	-6.31	-2.66	0.88	0	-0.28	-0.80
Change, %	66.7	-----	44.8	34.8	-----	13.6	82.7	51.3	66.7	0	0.11	0.27

TABLE A-9. NITRATE NITROGEN CONCENTRATION OF SOIL AFTER SPRAYING^a- TRIAL 3

Replication	Depth (cm)	Treatment		
		A	B	C
		ppm/acre		
1	6	10	10	10
	12	10	10	10
	18	10	10	10
2	6	10	10	10
	12	10	10	10
	18	10	10	10
3	6	10	10	10
	12	10	10	10
	18	10	10	10
4	6	10	10	10
	12	10	10	10
	18	10	10	10

^aAll entries < 10 ppm.TABLE A-10. CHLORIDE CONCENTRATION OF SOIL AFTER SPRAYING^a- TRIAL 3

Replication	Depth (cm)	A	B	C
1	6	25	25	25
	12	25	25	25
	18	25	25	25
2	6	25	25	25
	12	25	25	25
	18	25	25	25
3	6	25	25	25
	12	25	25	25
	18	25	25	25
4	6	25	25	25
	12	25	25	25
	18	25	25	25

^aAll entries < 25 ppm.